

# MODIS Cloud Mask

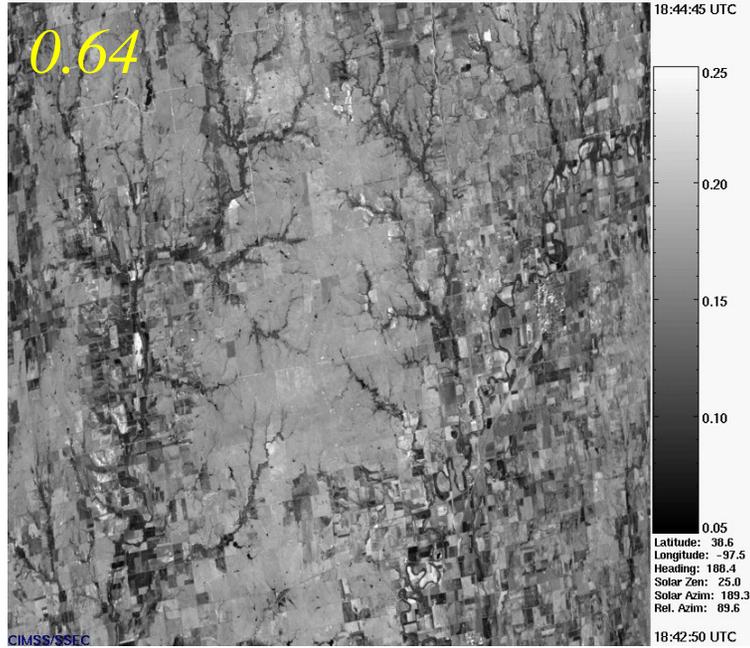
Ackerman, Frey, UW MODIS Group

- **1 km** nadir spatial resolution **day & night**, (250 m day)
  - **19 spectral bands (0.55-13.93  $\mu\text{m}$ , incl. 1.38  $\mu\text{m}$ )**  
11 spectral tests (function of 5 ecosystems) with "fuzzy" thresholds
  - temporal consistency test over ocean, desert (nighttime);  
spatial variability test over ocean
- **48 bits per pixel** including individual test results and processing path; generation of clear sky maps
- **bits 1,2** give combined test results as: *confident clear*, *probably clear*, *probably cloudy*, *obstructed/cloudy* (clear sky conservative)

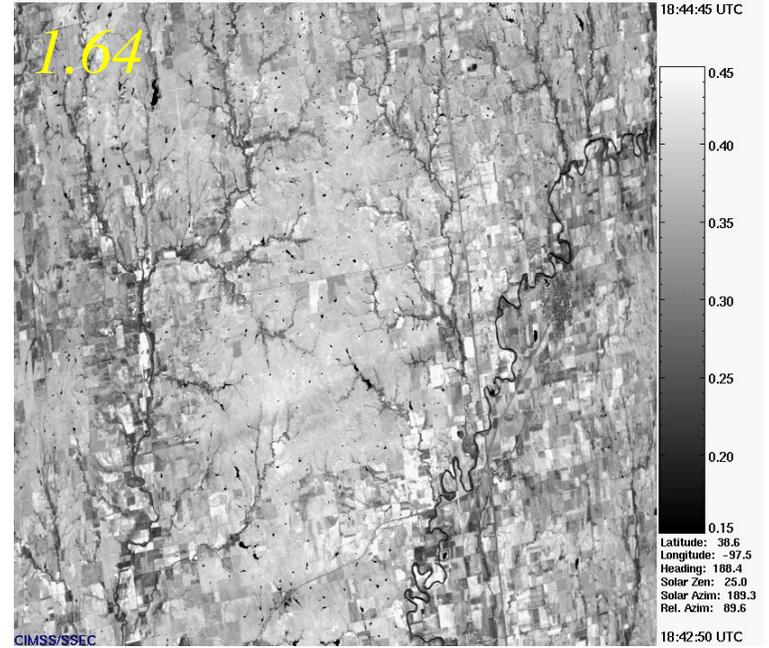
# Algorithm Development

- Built upon work done by others:
  - ISCCP – Rossow and Garder 1993
  - CLAVR – Stowe et al. 1991
  - APOLLO – Saunders and Kriebel 1988
- New spectral channels – new tests
  - 1.38 micron high cloud reflectance test
- Many spectral channels
  - more tests go into final product
  - first platform with 8-11 (can use tri-spectral tests)

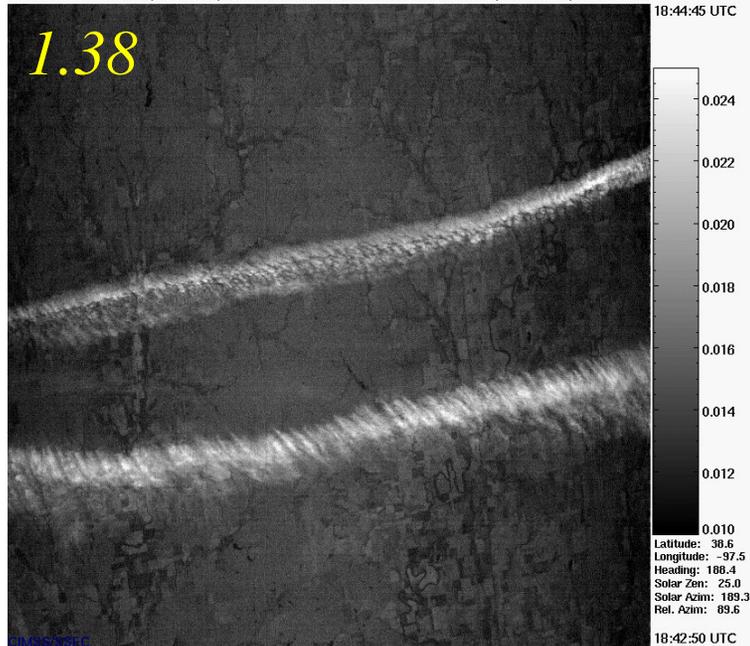
MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 02 (0.64 micron) Reflectance



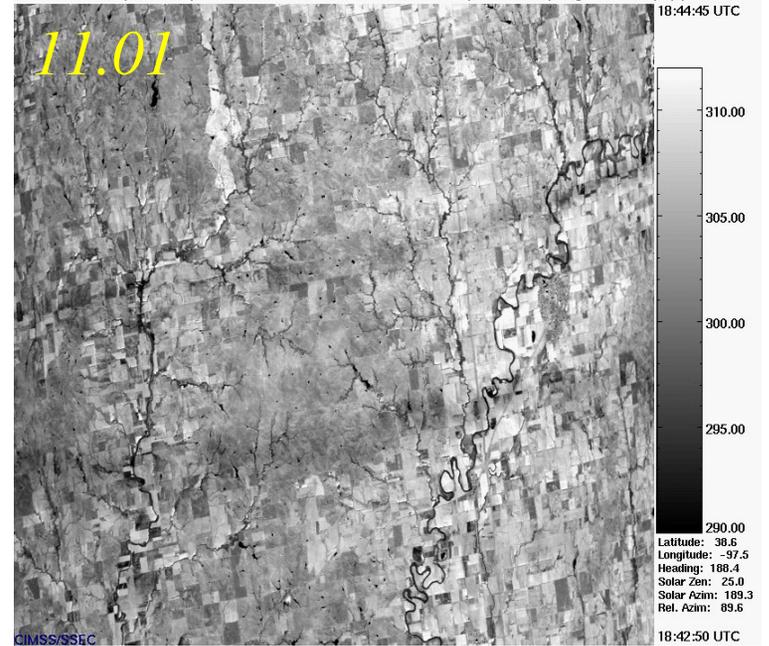
MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 10 (1.64 micron) Reflectance



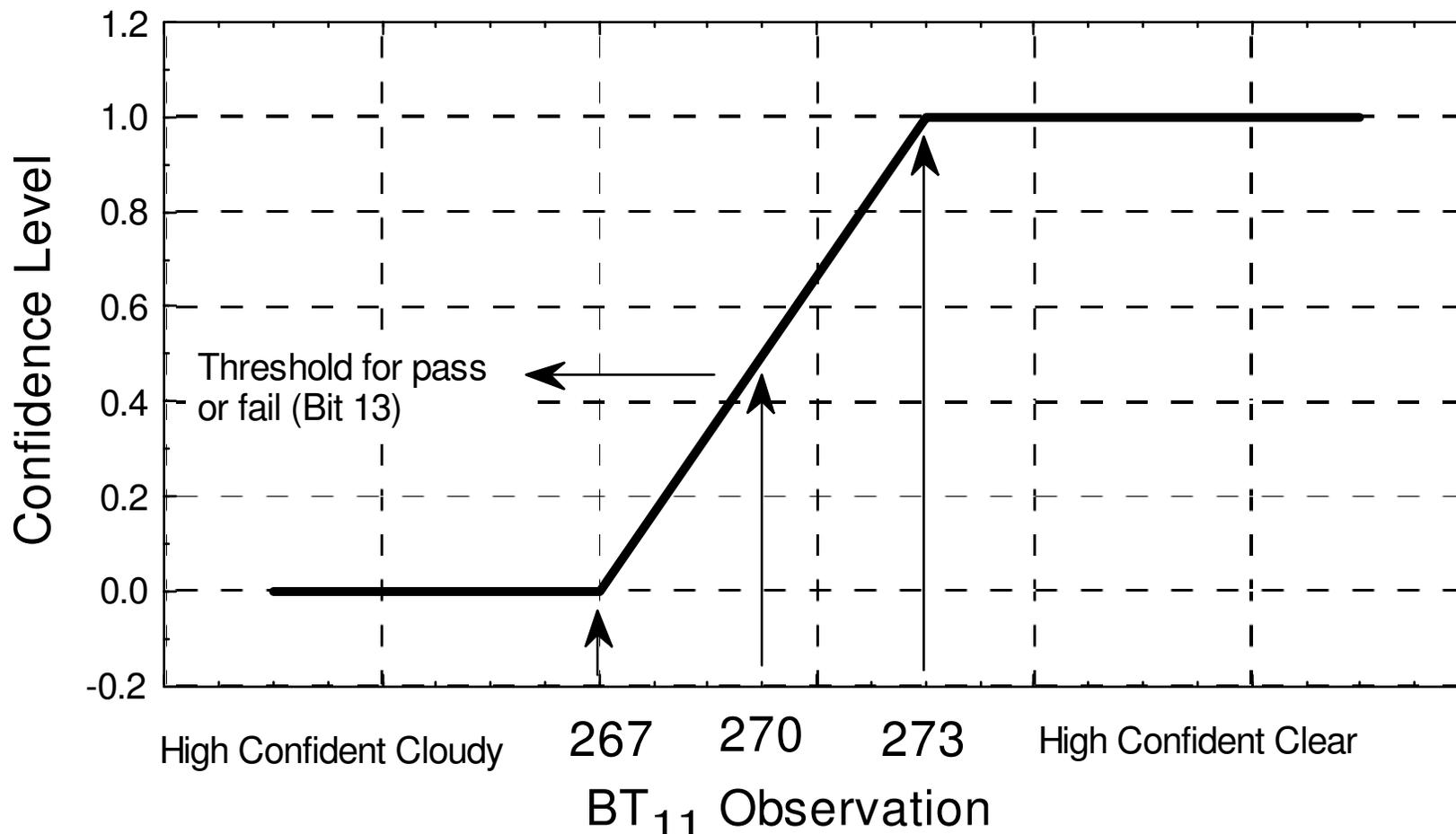
MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 15 (1.90 micron) Reflectance



MAS (SUCCESS) 1996/04/26 18:43:48 UTC Track 03, Band 45 (11.01 micron) Brightness Temp. (K)

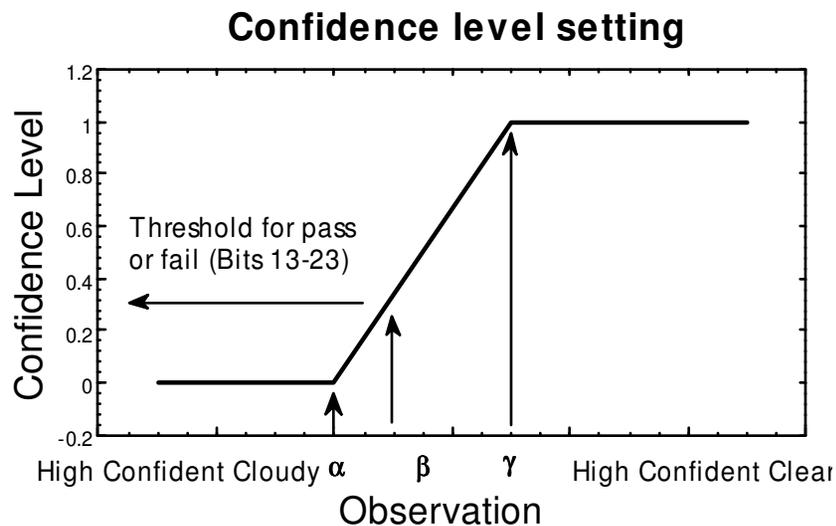


# Confidence Level of Clear



Example thresholds for the simple IR window cold cloud test.

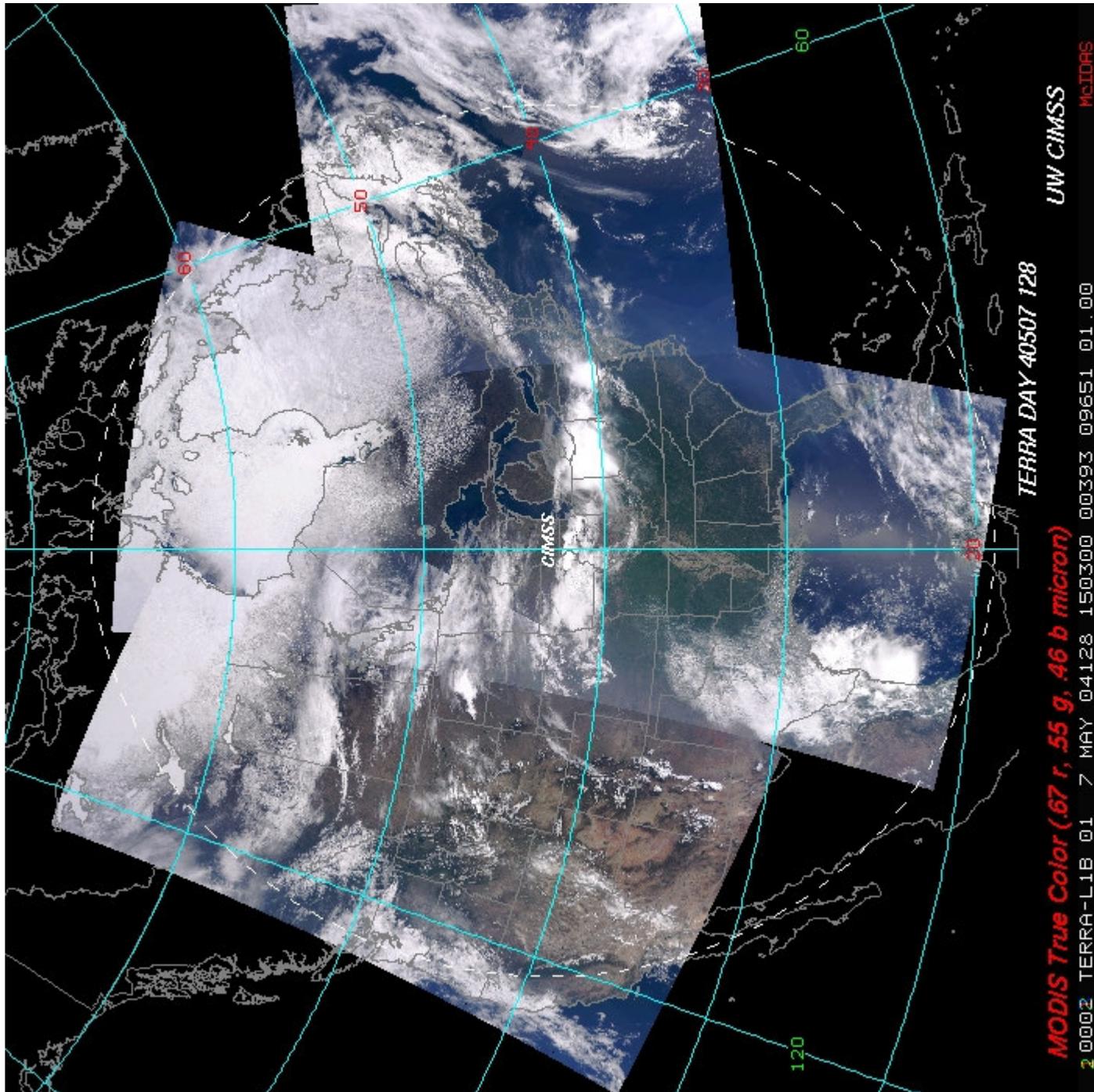
# Quality Flags



- ❑ Each test returns a confidence (F ) ranging from 0 to 1.
- ❑ Similar tests are grouped and minimum confidence selected [  $\min (F_i )$  ]
- ❑ Quality Flag is

$$Q = \sqrt[N]{\prod_{i=1}^N \min(F_i)}$$

- ❑ Four values; 0, >.66, >.95 and >.99



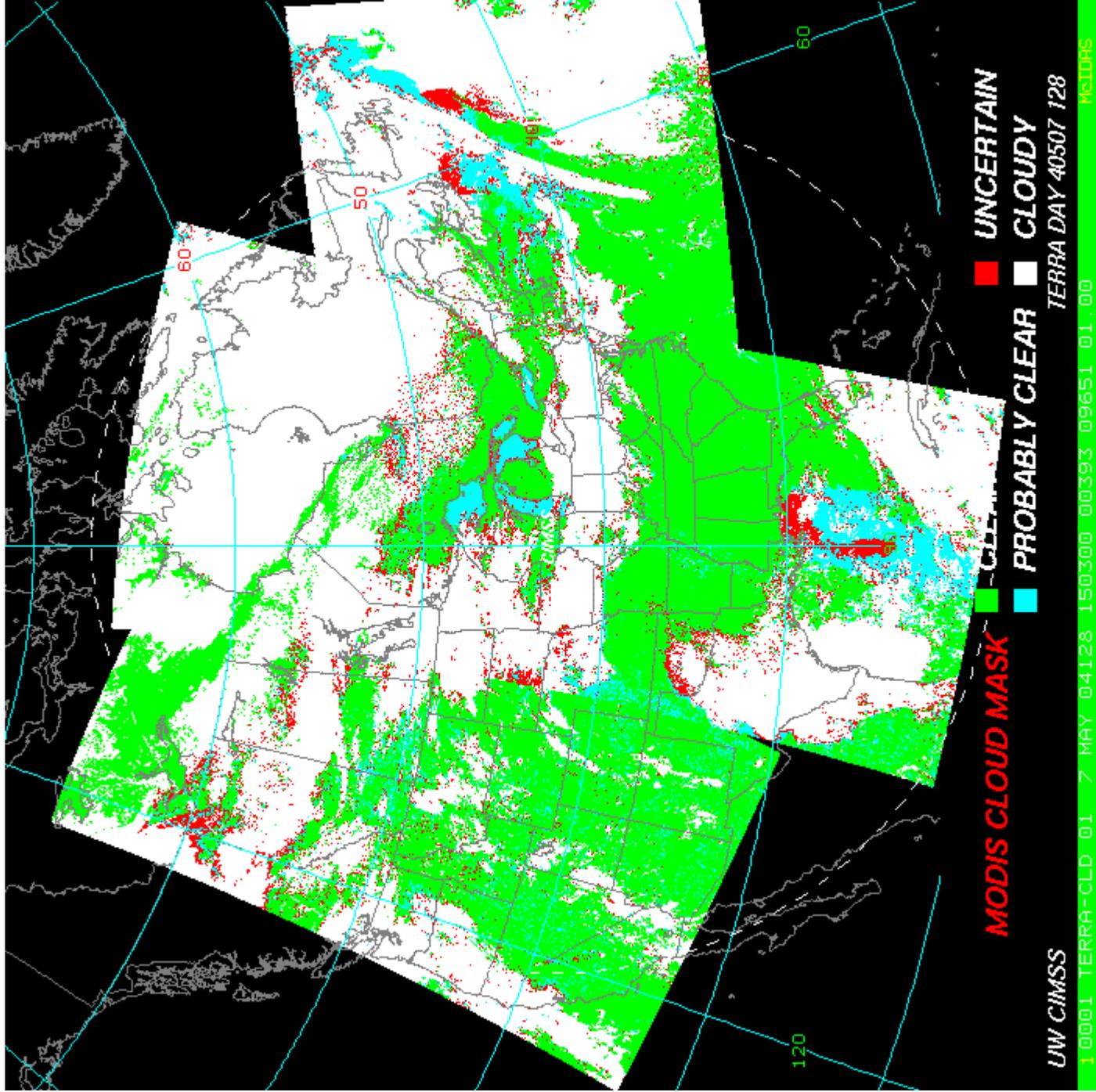
TERRA DAY 40507 128

**MODIS True Color (.67 r, .55 g, .46 b micron)**

2 0002 TERRA-L1B 01 7 MAY 04128 150300 00393 09651 01.00

UW CIMSS

McIDAS



# Output Product Description

bit field	Description Key	Result
0	Cloud Mask Flag	0 = not determined 1 = determined
1-2	Unobstructed FOV Confidence Flag	00 = cloudy 01 = uncertain 10 = probably clear 11 = confident clear
3	Day / Night Flag	0 = Night / 1 = Day
4	Sun glint Flag	0 = Yes / 1 = No
5	Snow / Ice Background Flag	0 = Yes / 1 = No
6-7	Land / Water Flag	00 = Water 01 = Coastal 10 = Desert 11 = Land
8	Non-cloud obstruction Flag (heavy aerosol)	0 = Yes / 1 = No
9	Thin Cirrus Detected (solar)	0 = Yes / 1 = No
10	Shadow Found	0 = Yes / 1 = No
11	Thin Cirrus Detected (infrared)	0 = Yes / 1 = No
12	Cloud adjacency (not used)	
13	Cloud Flag – Ocean IR Threshold Test	0 = Yes / 1 = No
14	High Cloud Flag - CO2 Threshold Test	0 = Yes / 1 = No
15	High Cloud Flag – 6.7 $\mu\text{m}$ Test	0 = Yes / 1 = No

16	High Cloud Flag – 1.38 $\mu\text{m}$ Test	0 = Yes / 1 = No
17	High Cloud Flag – 3.7-12 $\mu\text{m}$ Test (night only)	0 = Yes / 1 = No
18	Cloud Flag - IR Temperature Difference Tests	0 = Yes / 1 = No
19	Cloud Flag - 3.9-11 $\mu\text{m}$ Test	0 = Yes / 1 = No
20	Cloud Flag – Visible Reflectance Test	0 = Yes / 1 = No
21	Cloud Flag – Visible Ratio Test	0 = Yes / 1 = No
22	Clear-sky Restoral Test-NDVI in Coastal Areas	0 = Yes / 1 = No
23	Cloud Flag – Land and Polar Night 7.3-11 $\mu\text{m}$ Test	0 = Yes / 1 = No
24	Cloud Flag - Temporal Consistency (not used)	0 = Yes / 1 = No
25	Clear-sky Restoral Test – Spatial Consistency (ocean)	0 = Yes / 1 = No
26	Clear-sky Restoral Tests (land and sun-glint)	0 = Yes / 1 = No
27	Cloud Flag – Night Surface Temperature Test	0 = Yes / 1 = No
28	Suspended Dust Flag	0 = Yes / 1 = No
29	Cloud Flag - Night Ocean 8.6 - 7.3 $\mu\text{m}$ Test	0 = Yes / 1 = No
30	Cloud Flag – Night Ocean 11 $\mu\text{m}$ Variability Test	0 = Yes / 1 = No
31	Spare	

## Collection 5 Changes

### Polar night:

new 3.9-12  $\mu\text{m}$  BTD cloud test (after Liu)

threshold a function of observed 11 $\mu\text{m}$   $T_{\text{bb}}$

added 7.3-11  $\mu\text{m}$  BTD cloud test (after Liu)

threshold a function of observed 11 $\mu\text{m}$   $T_{\text{bb}}$

added 7.3-11  $\mu\text{m}$  BTD clear-sky restoral test (after Liu)

threshold of +5K (restores to clear)

new 11-12  $\mu\text{m}$  BTD cloud test (after Key)

threshold a function of observed 11 $\mu\text{m}$   $T_{\text{bb}}$  and viewing zenith angle

added thresholds for lower observed 11 $\mu\text{m}$   $T_{\text{bb}}$  (to 190K)

### Land night:

new 11-12  $\mu\text{m}$  BTD cloud test (after Key)

as in polar night

added land surface temperature cloud test

also added to non snow-covered polar land night

not performed in bare desert or high elevation regions

GDAS estimated surface temperature minus observed 11 $\mu\text{m}$   $T_{\text{bb}}$

basic thresholds of 10K for vegetated land, 20K for arid and semi-arid land

viewing zenith and water vapor correction

confidence limits of +,- 2K

## Night water:

new 11-12  $\mu\text{m}$  BT cloud test (after Key)

threshold a function of observed 11 $\mu\text{m}$   $T_{\text{bb}}$  and viewing zenith angle

added thresholds for lower observed 11 $\mu\text{m}$   $T_{\text{bb}}$  (to 190K)

added SST cloud test

Reynolds Blended SST minus observed 11  $\mu\text{m}$   $T_{\text{bb}}$

basic threshold of 6K

viewing zenith and water vapor correction

confidence limits of  $-2.0\text{K}$  (high) and  $+1.0\text{K}$  (low)

added 8.6-7.3  $\mu\text{m}$  BT cloud test

threshold of 17K

confidence limits of  $\pm 1.0\text{K}$

new 11  $\mu\text{m}$  BT variability cloud test

count how many of 8 surrounding pixels satisfy the following condition:

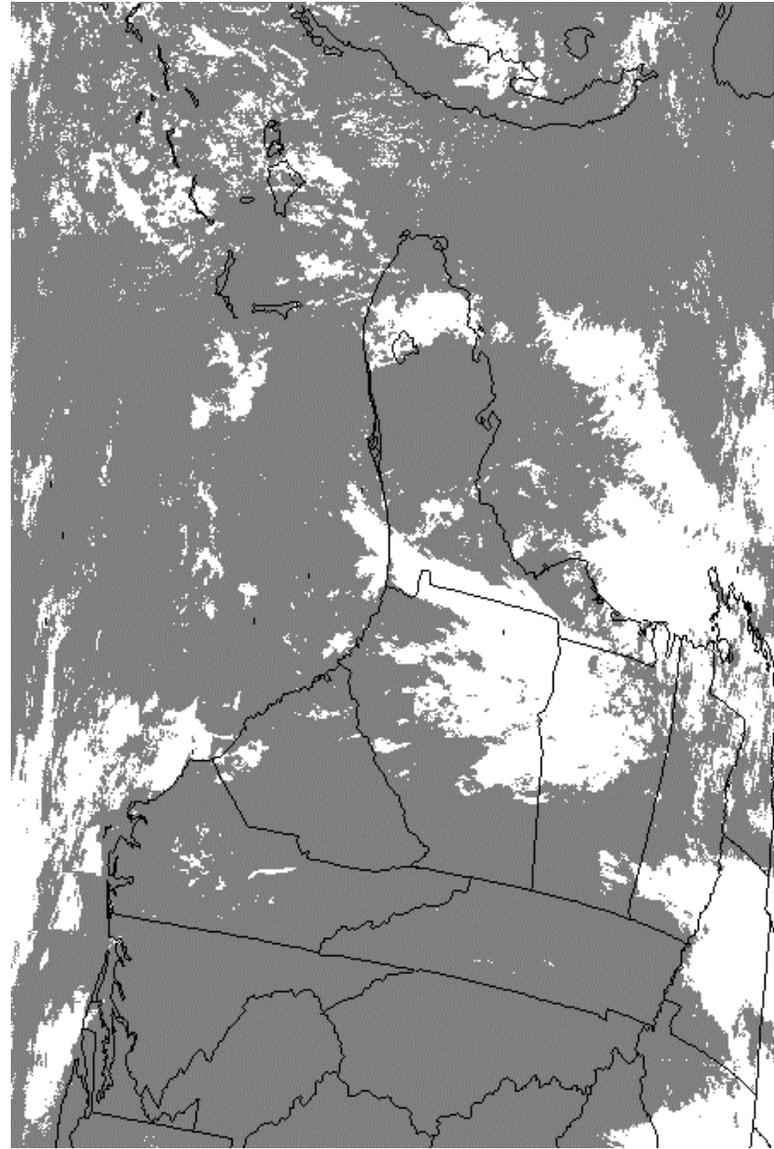
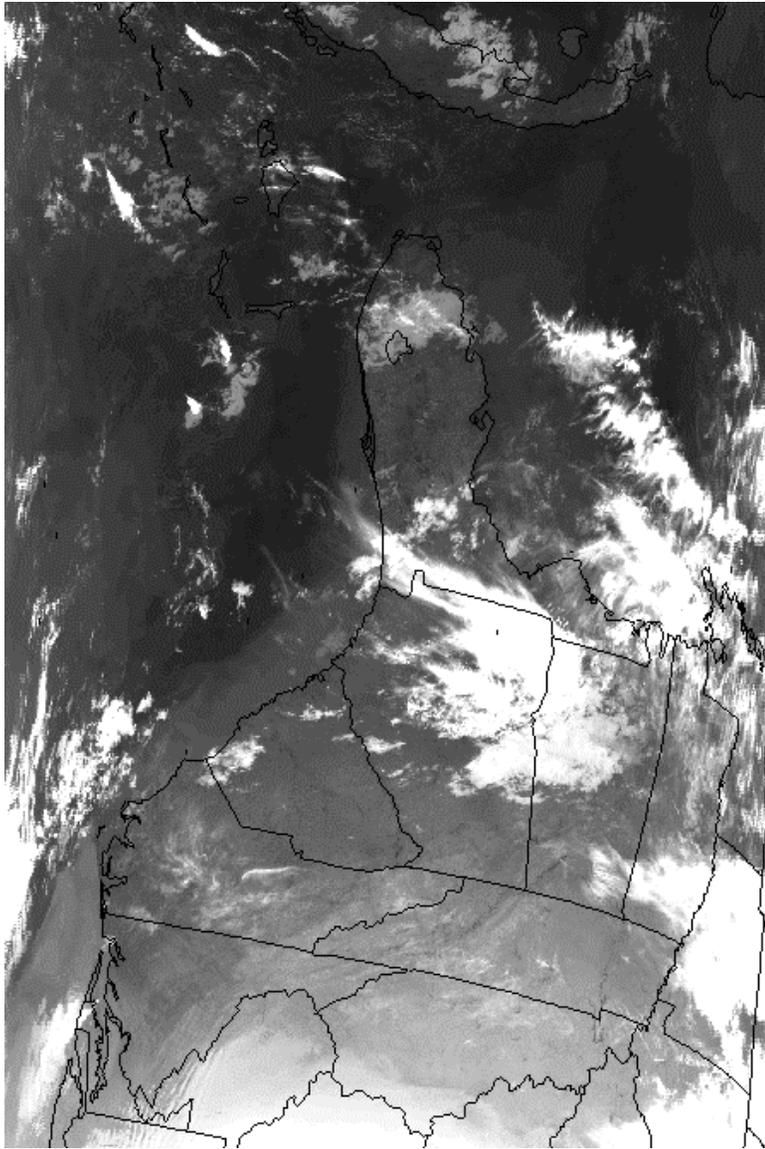
{11  $\mu\text{m}$   $T_{\text{bb}}$  of adjacent pixel minus that of current pixel  $\leq 0.5\text{K}$ }

higher count means greater likelihood of clear sky

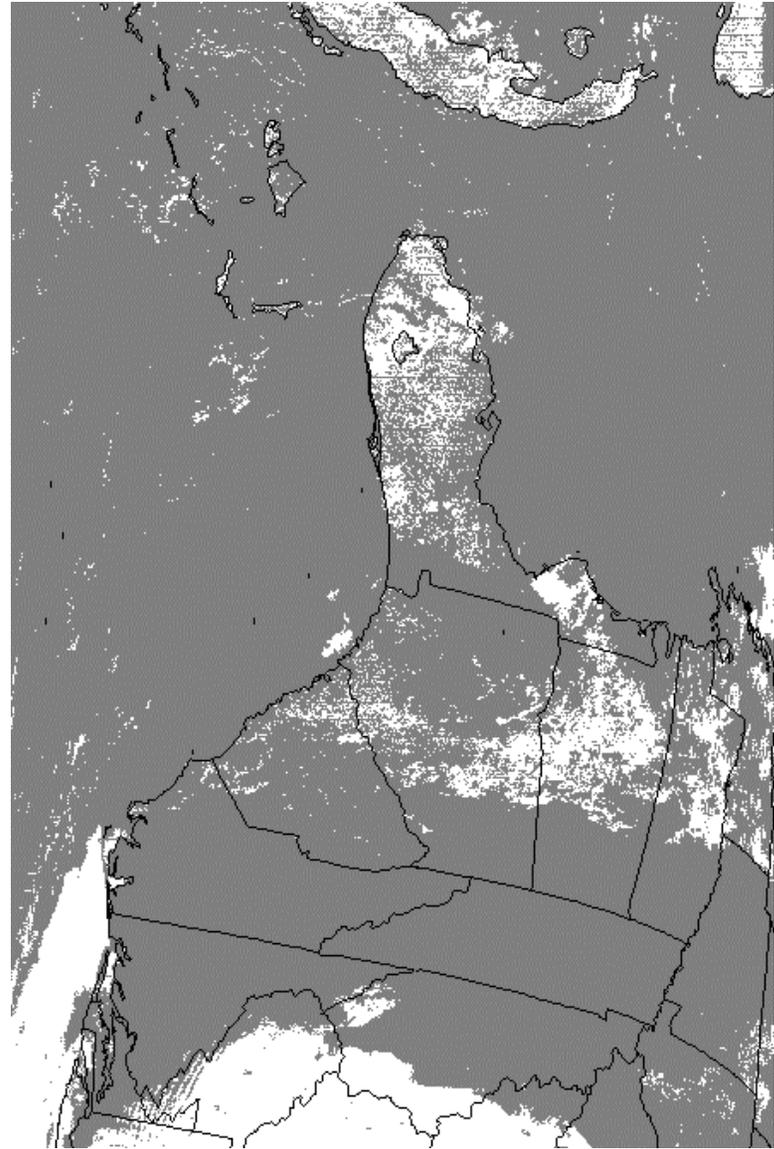
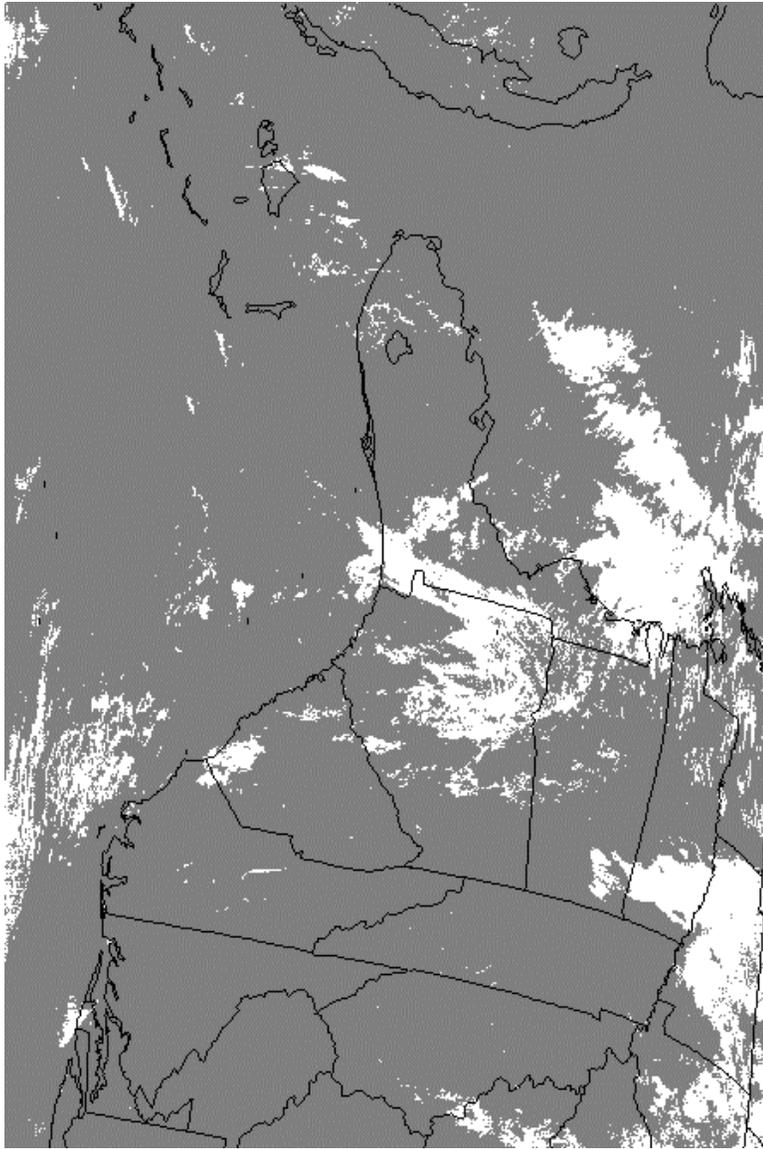
threshold of 6

confidence limits of 7 (high) and 3 (low)

finds cloud edges and single-pixel clouds

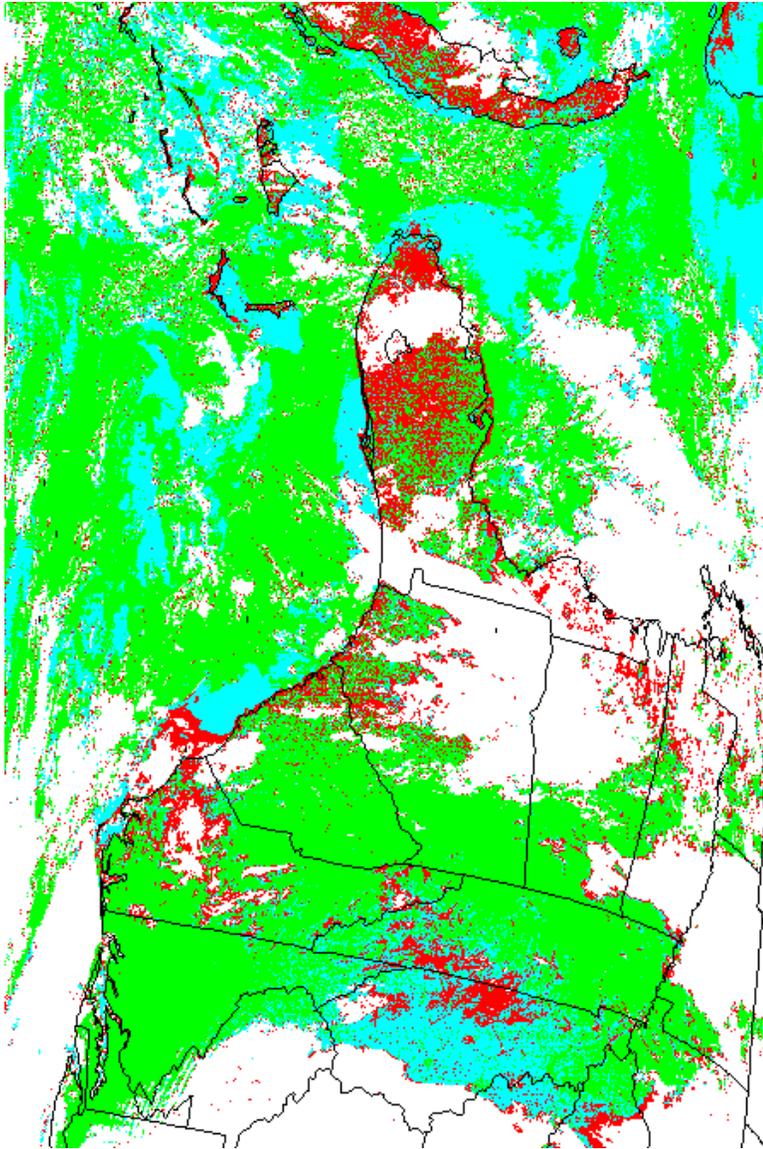


Terra MODIS data from April 6, 2003. Band 31 image on left, LST test results on right.

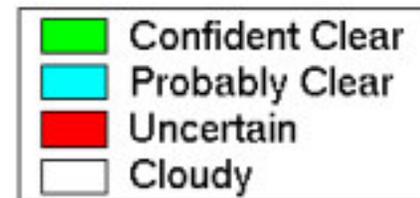


Results of 11-12  $\mu\text{m}$  test on left, 3.9 - 11  $\mu\text{m}$  test on right (0.5 confidence level).

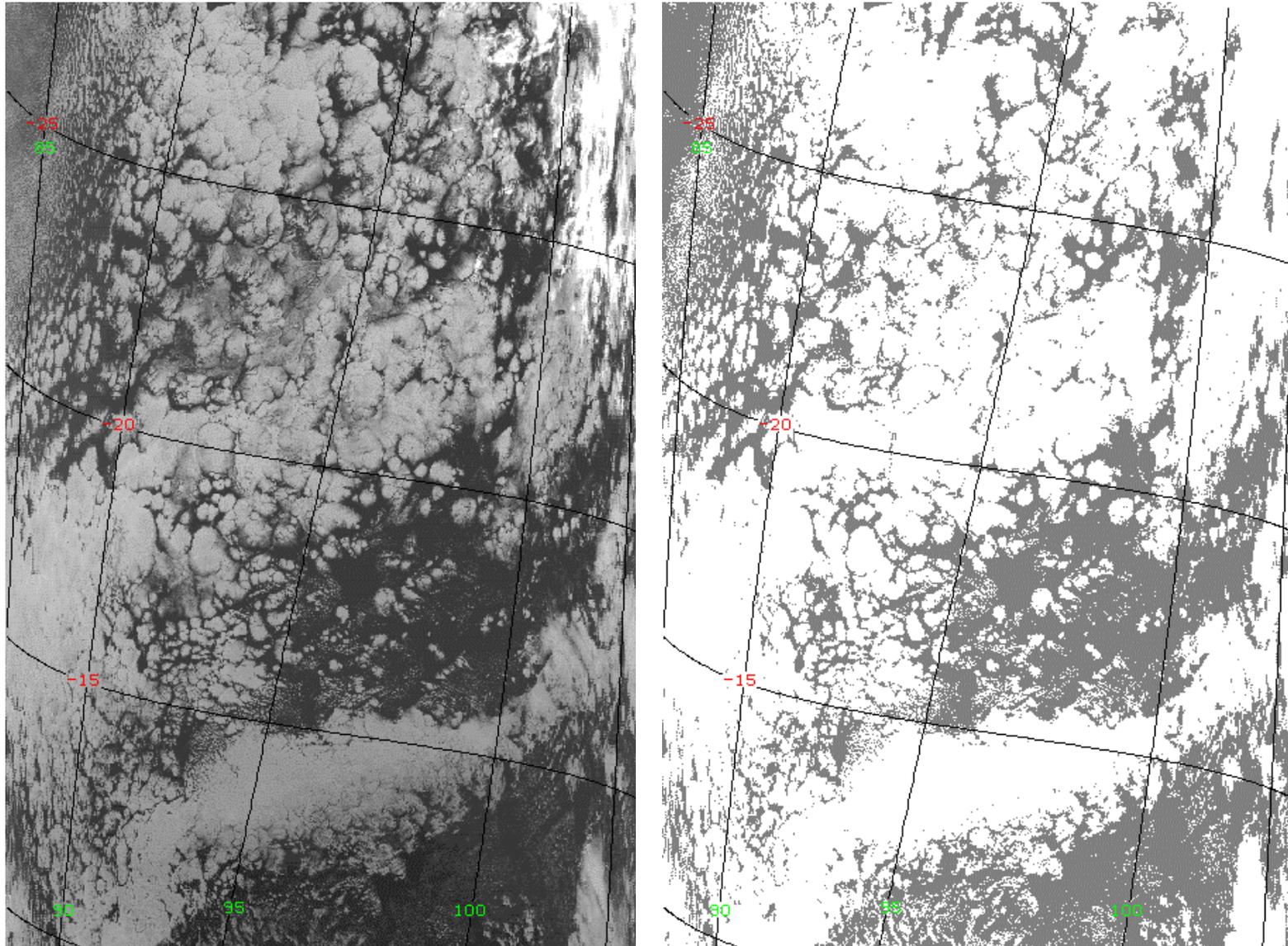
Collection 5 Terra cloud mask from 03:35 UTC, April 6, 2003.



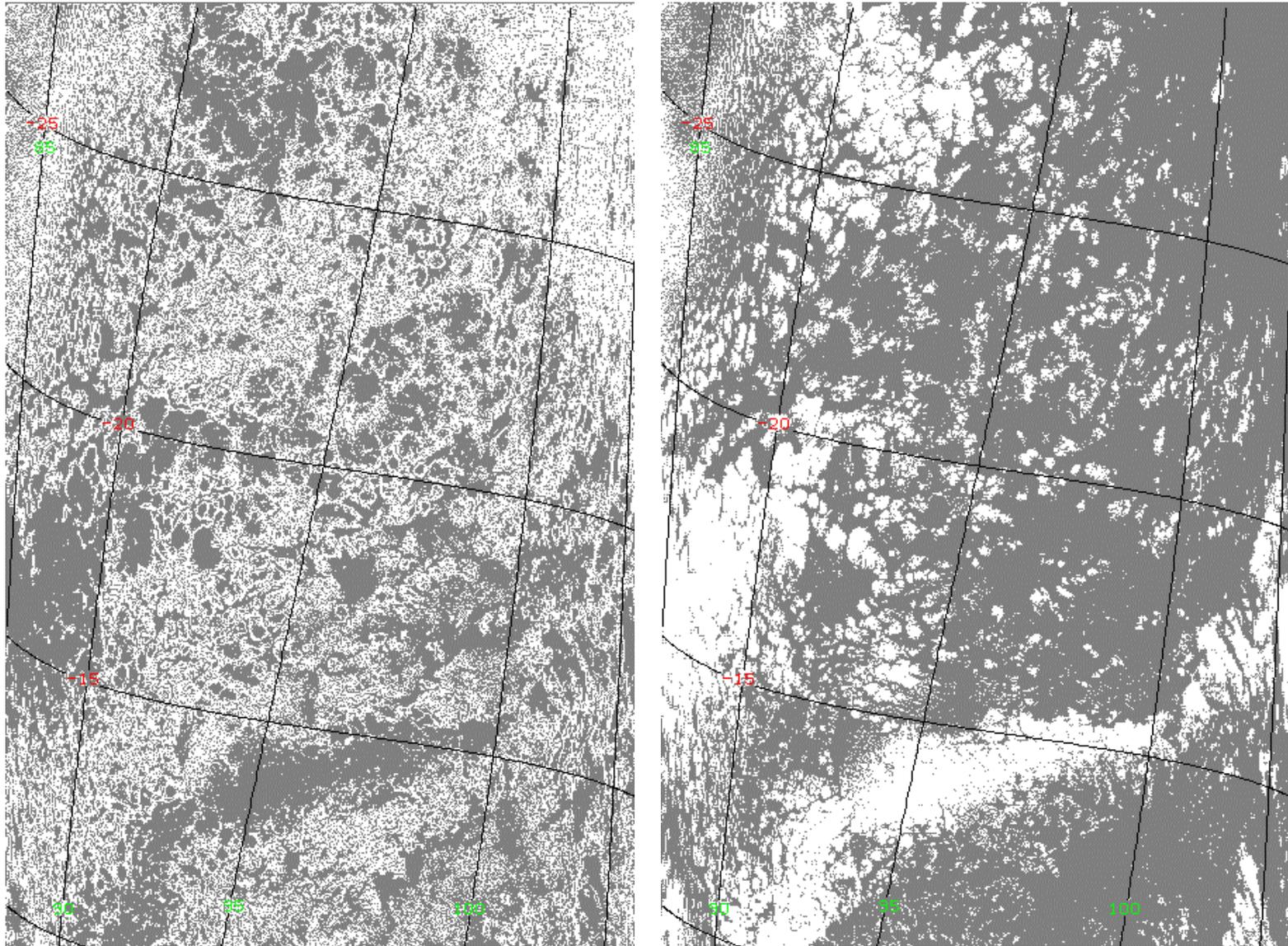
MODIS Cloud Mask



## Example Ocean Night Scene

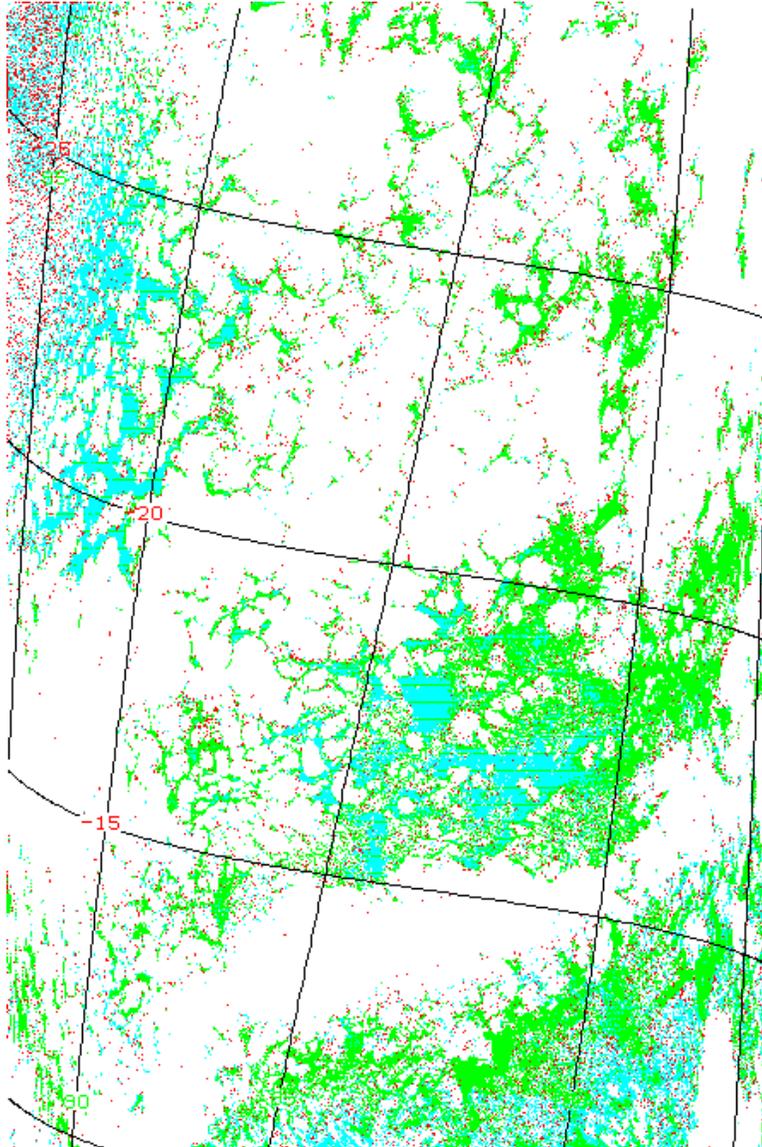


Terra MODIS data from April 6, 2003. Band 31 image on left, SST test results on right.

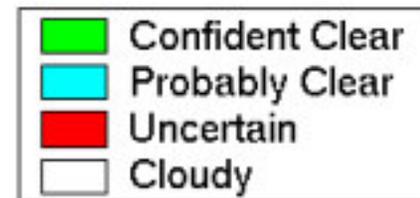


Results of 11 μm variability test at left, 3.9 - 11 μm test at right (0.5 confidence level).

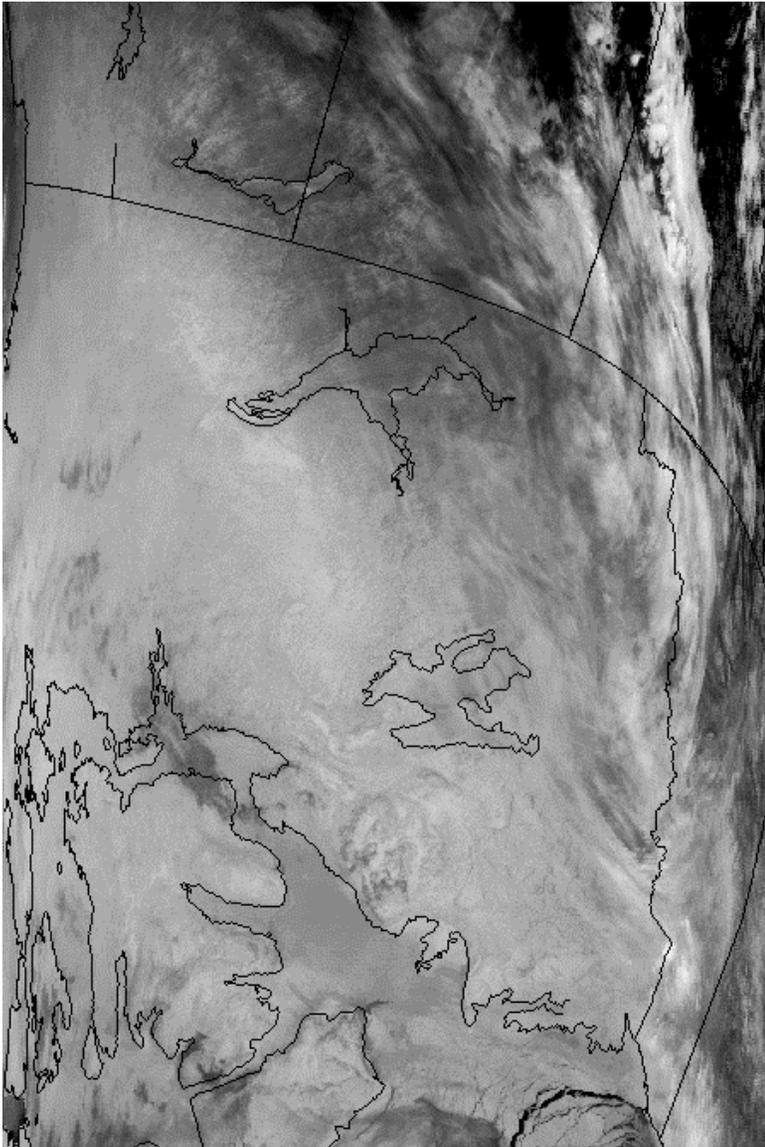
Collection 5 Terra Cloud Mask from 05:00 UTC, April 6, 2003.



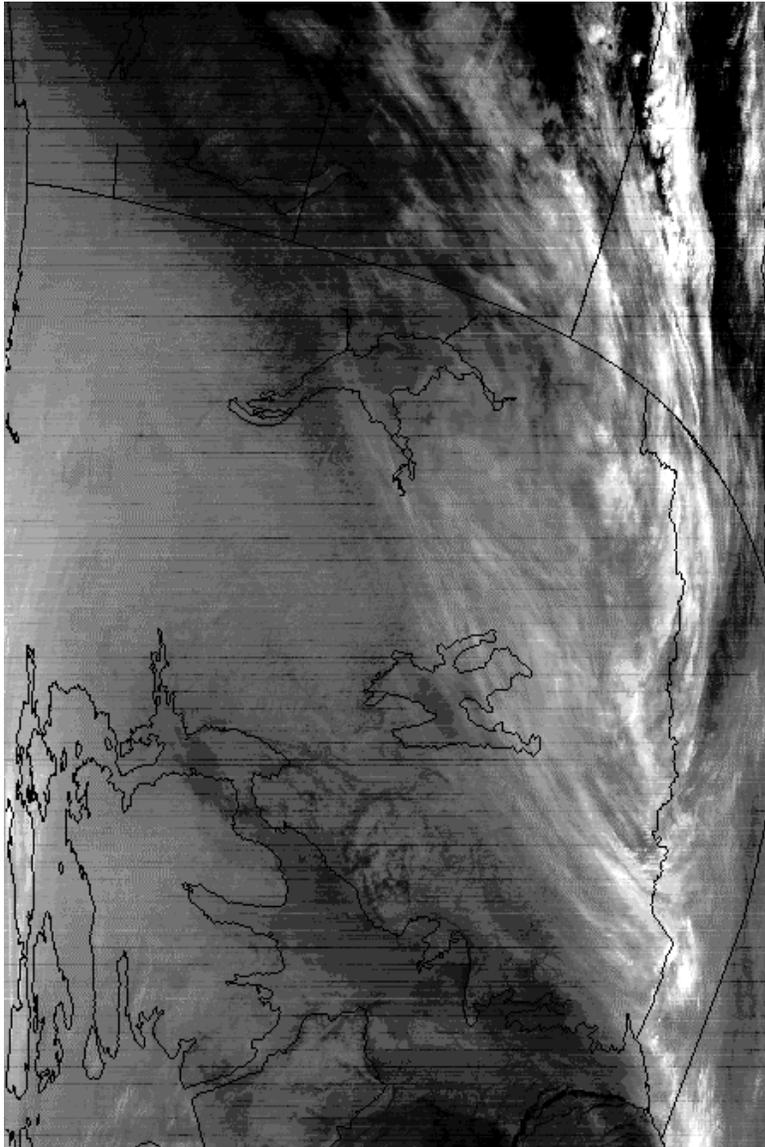
MODIS Cloud Mask



Terra 1-km IR Data from 05:05 UTC, April 1, 2003

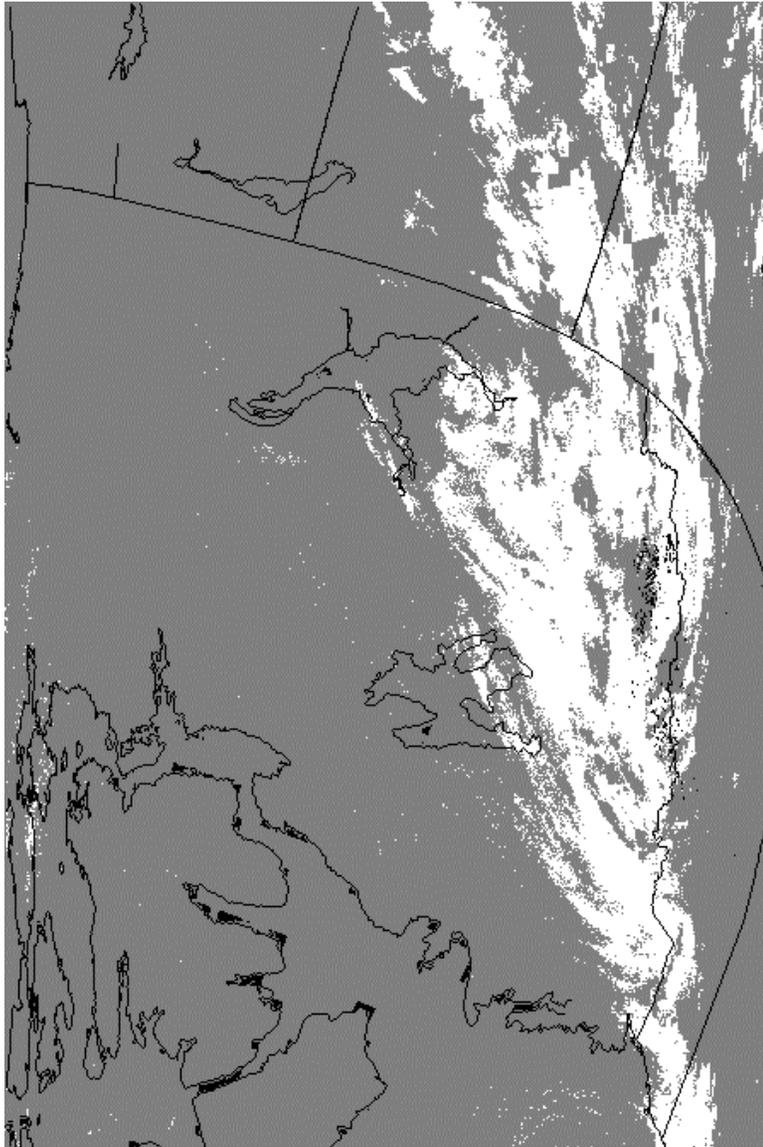


Band 31

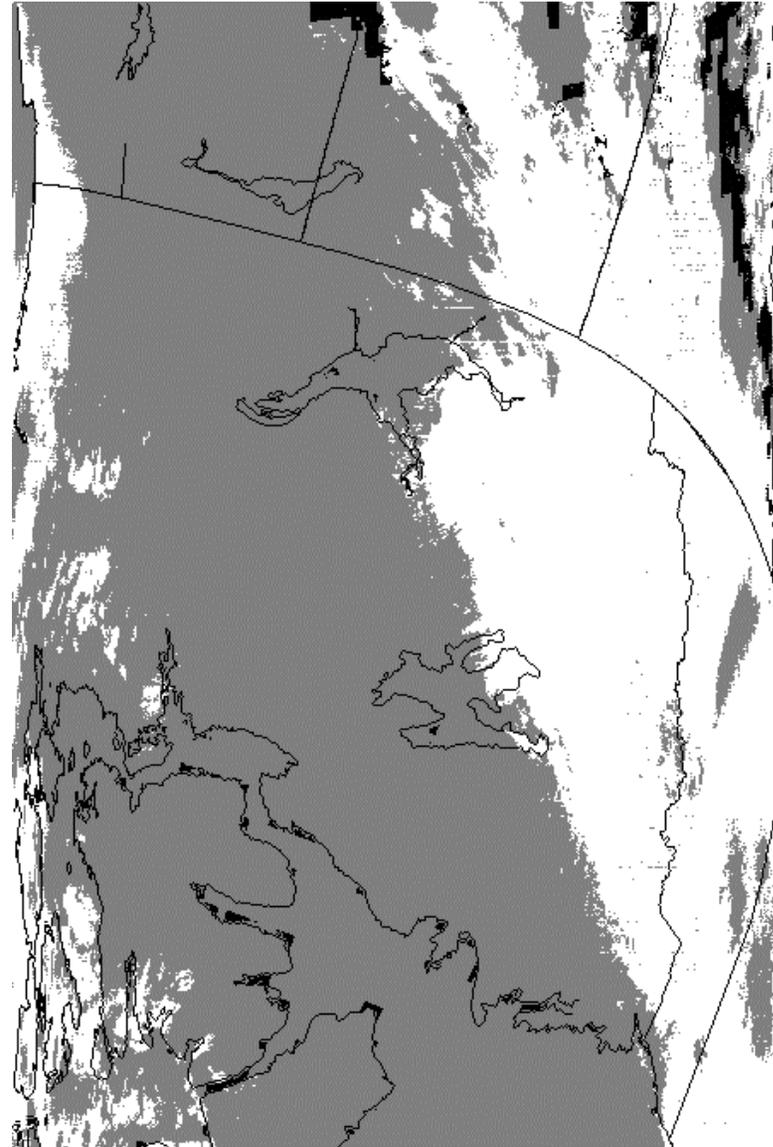


Band 28

Collection 5 Terra Cloud Mask from 05:05 UTC, April 1, 2003

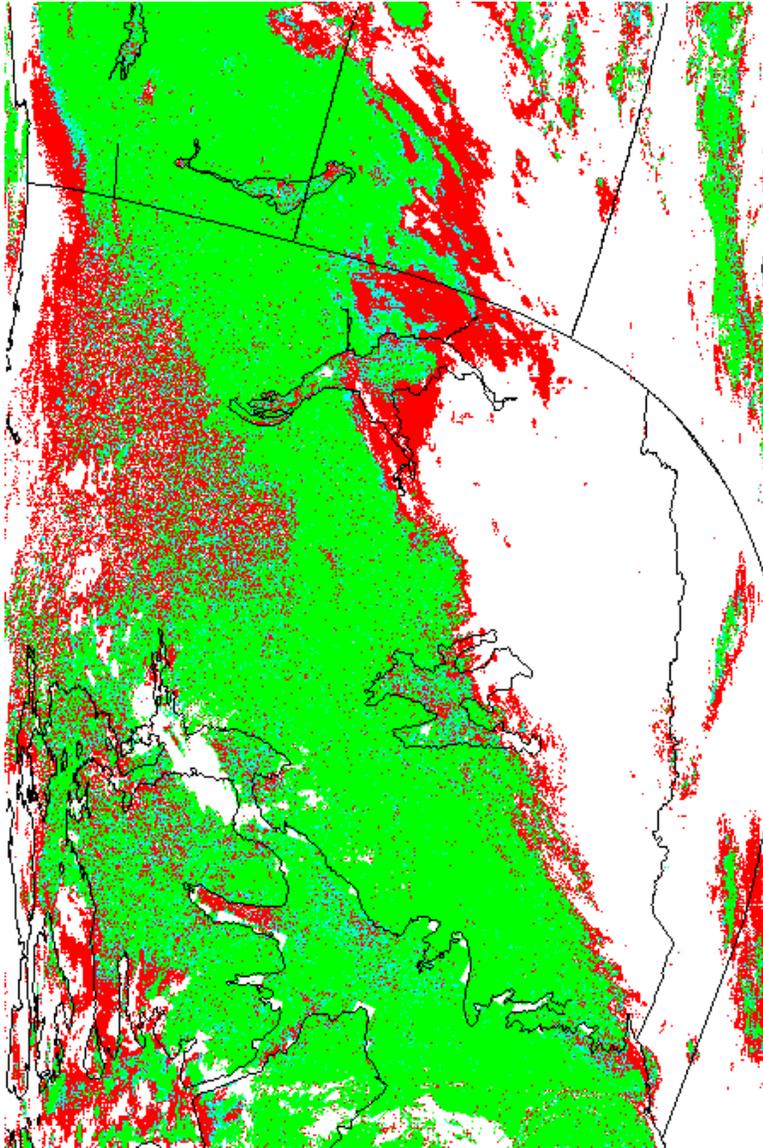


3.9-12  $\mu\text{m}$  Test

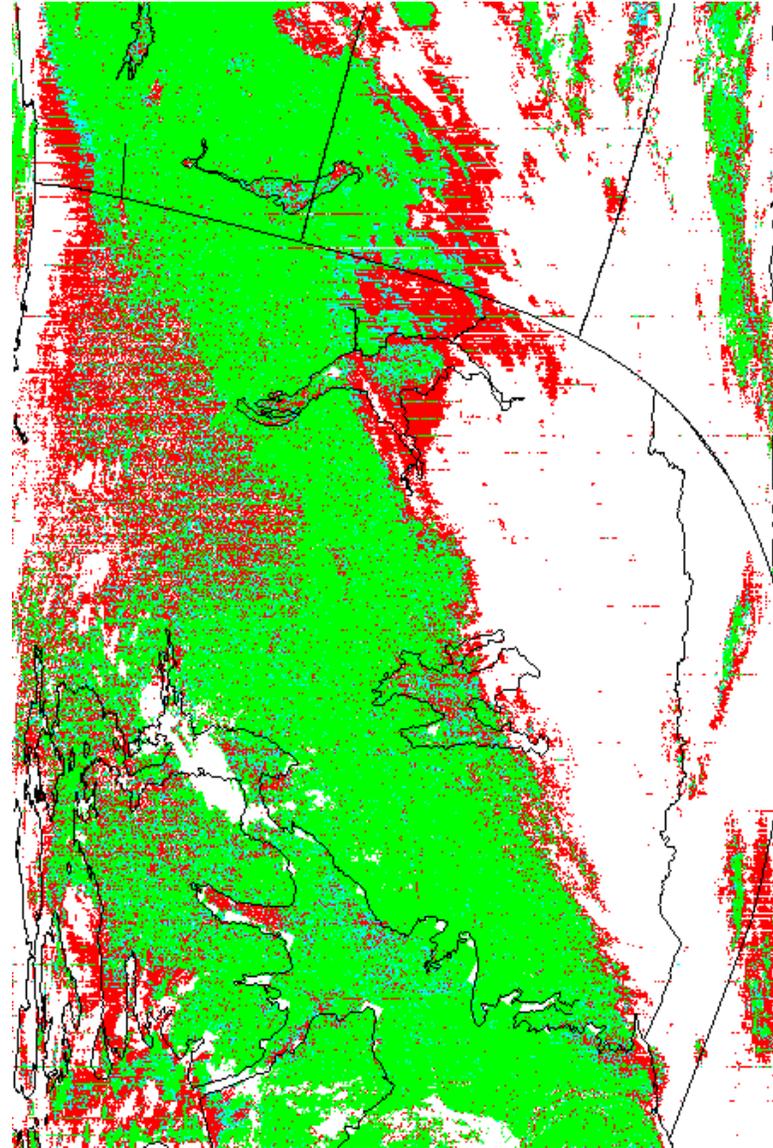


7.3-11  $\mu\text{m}$  Test

Collection 5 Terra Cloud Mask from 05:05 UTC, April 1, 2003

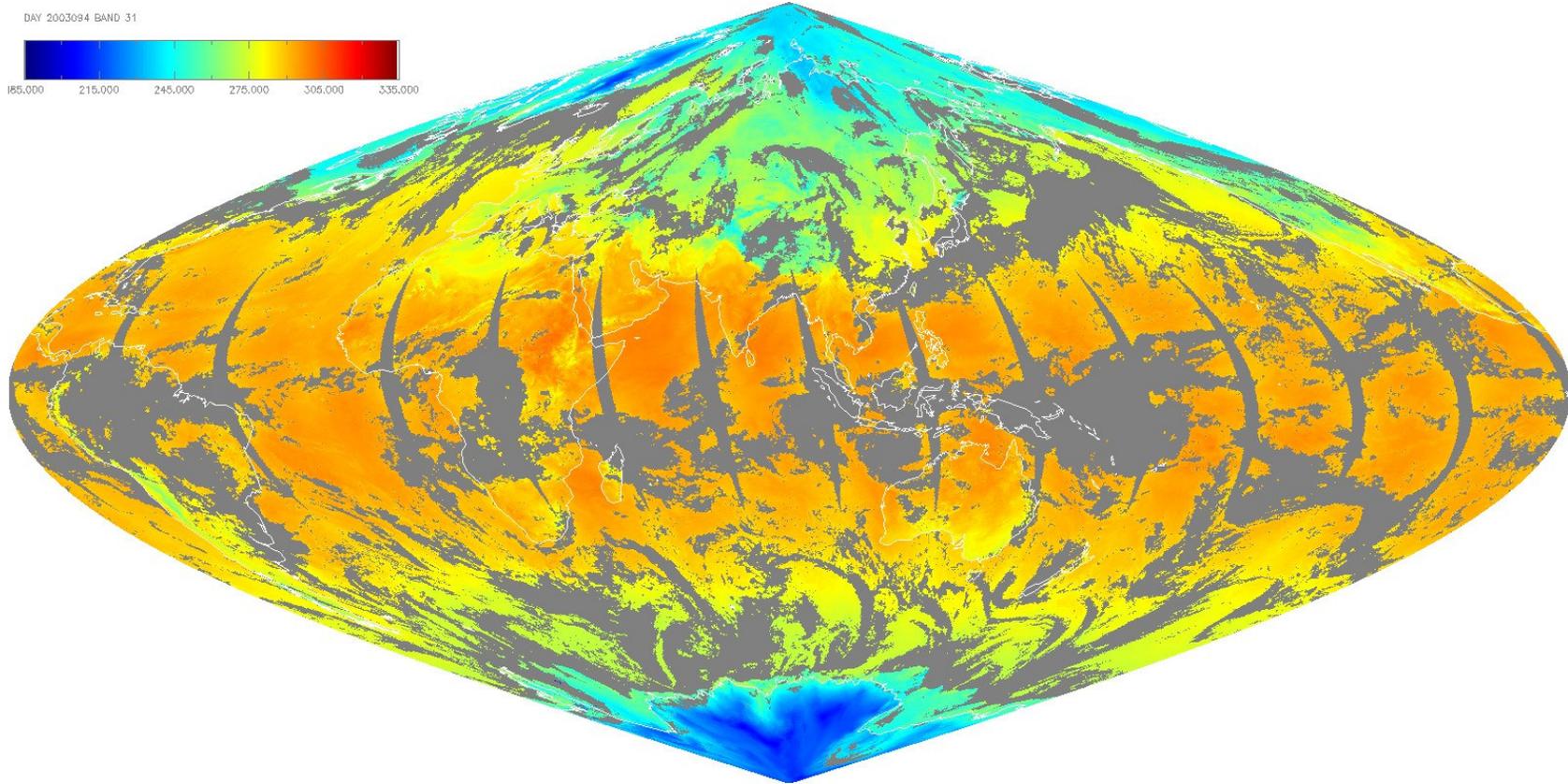


Using De-striping Algorithm (MOD\_PRDS)



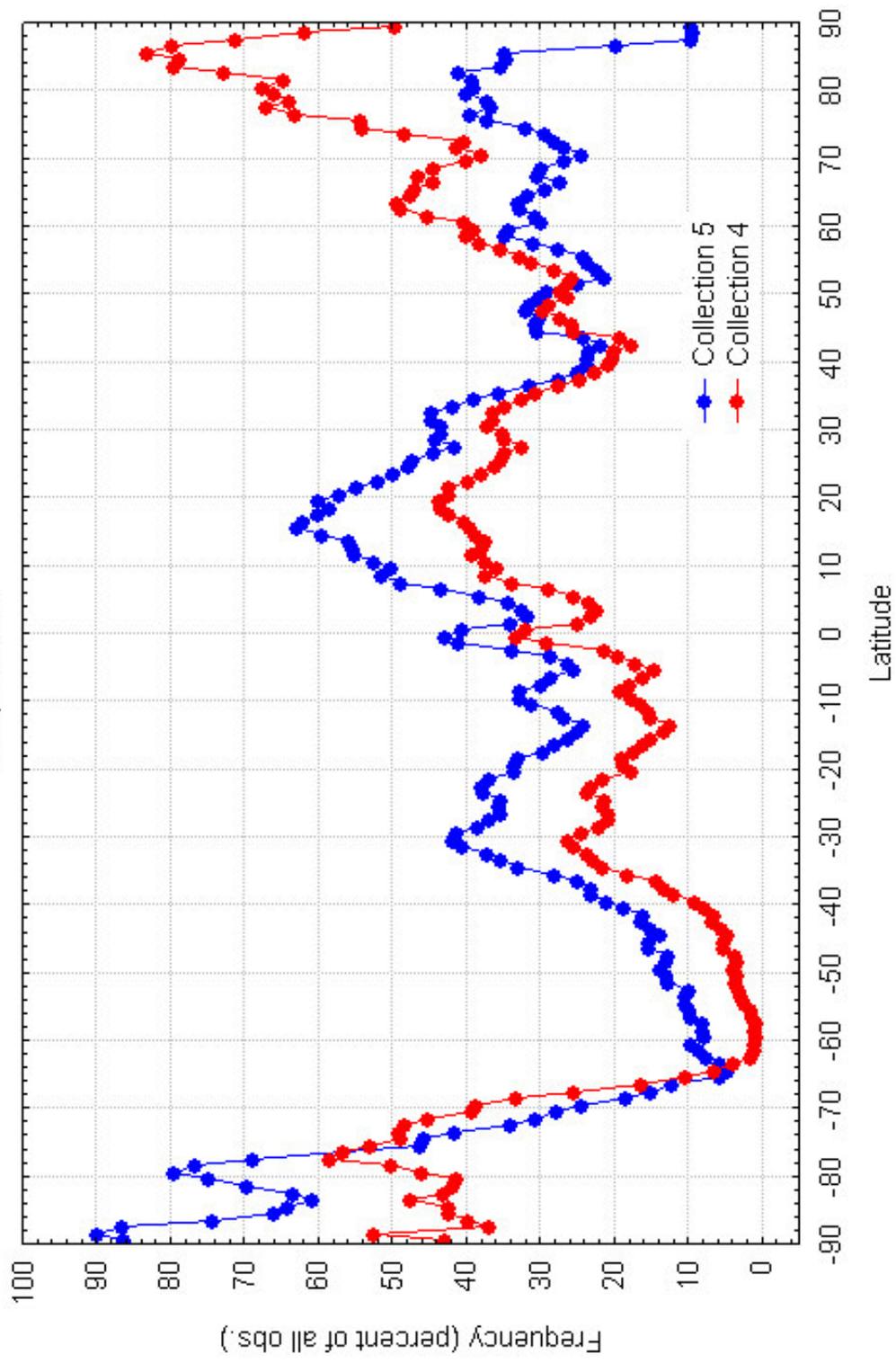
No De-striping

# Terra 11 $\mu\text{m}$ Collection 5 Night Clear-sky Brightness Temperatures

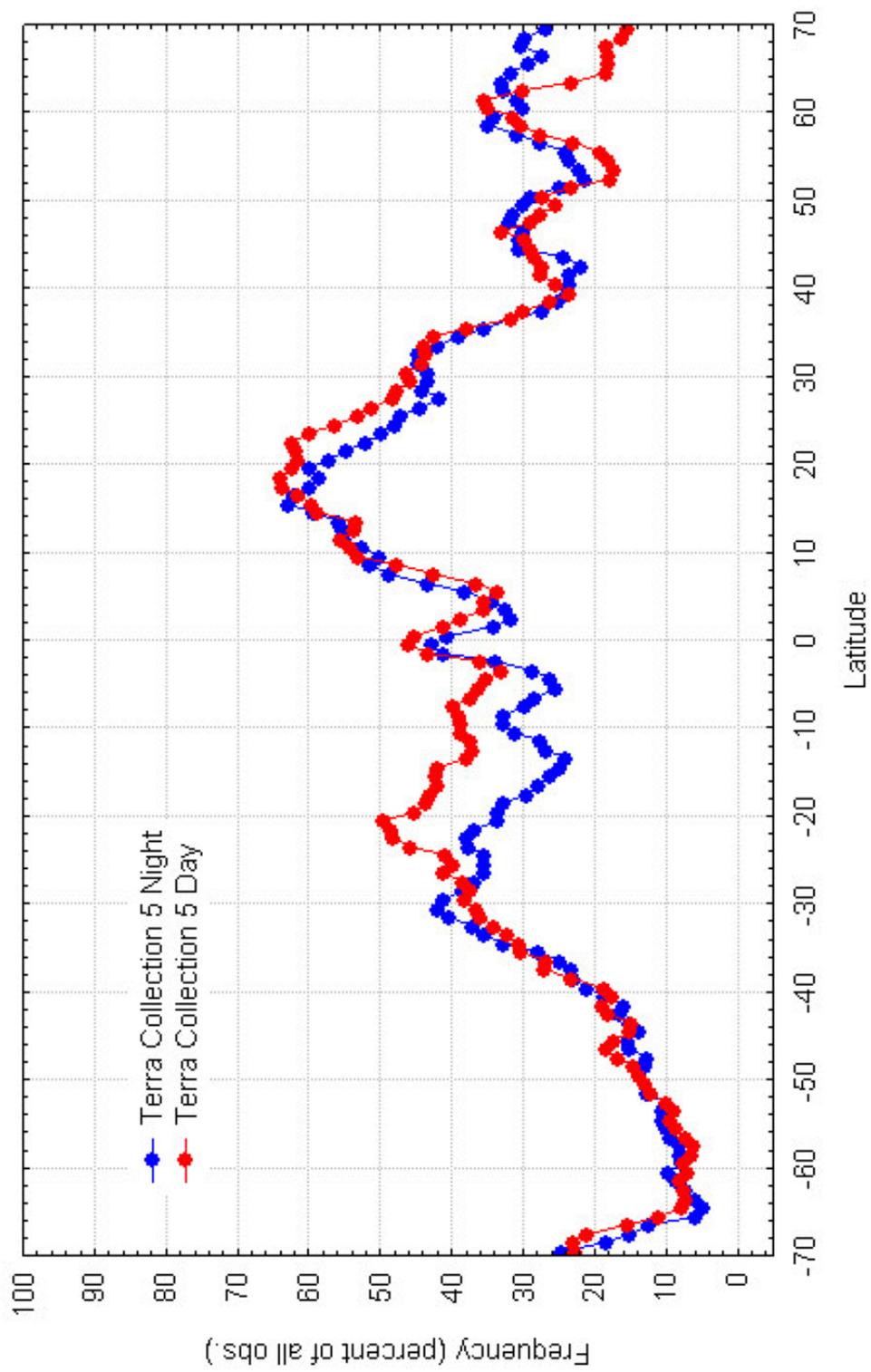


April 4, 2003

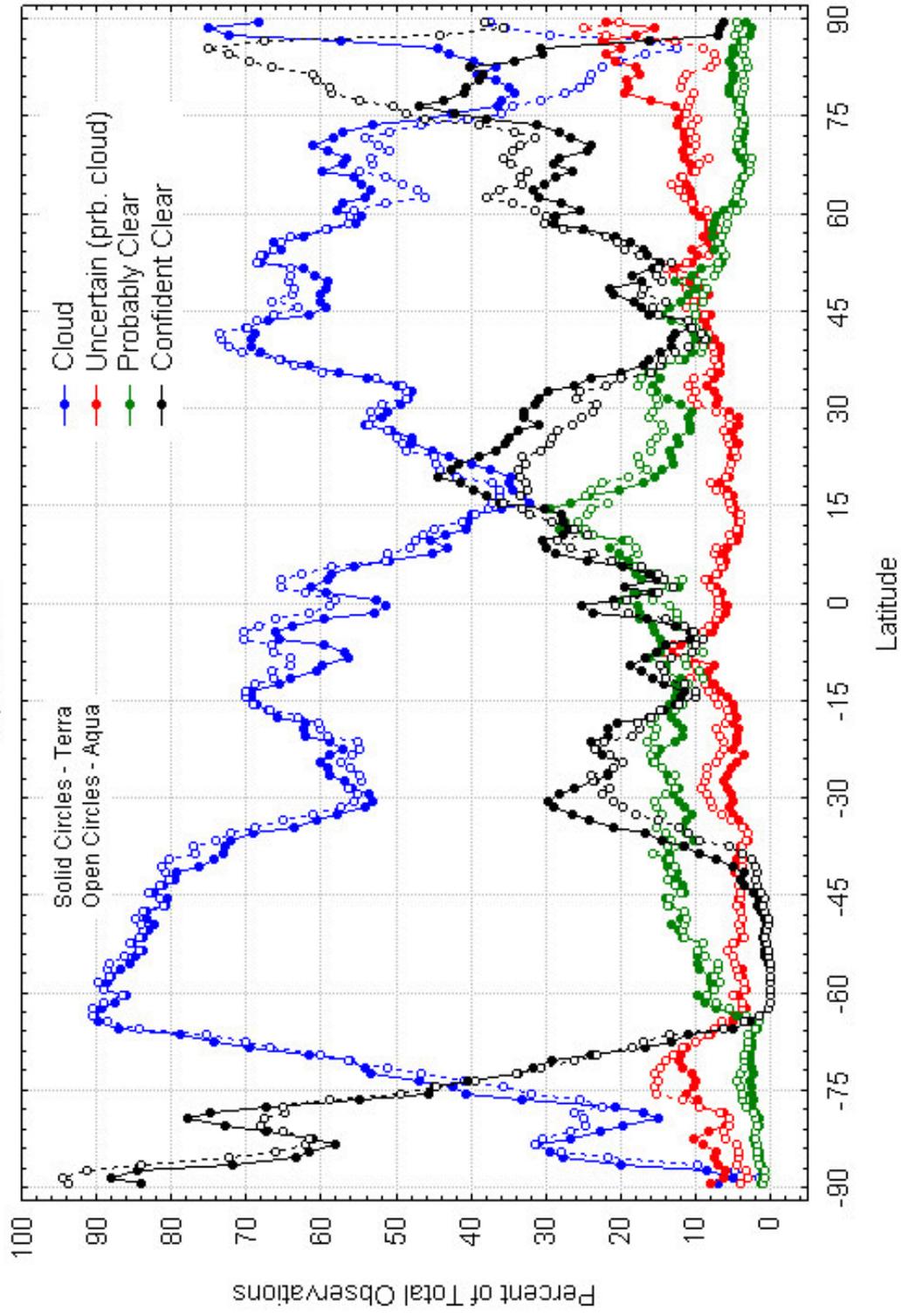
Zonal Mean Cloud Statistics from MODIS Cloud Mask  
Frequency of Nighttime Clear Sky  
04 April, 2003



Zonal Mean Cloud Statistics from MODIS Cloud Mask  
Frequency of Day and Night Clear Skies  
04 April, 2003



Terra and Aqua Nighttime Zonal Cloud Frequency  
April 4, 2003



# MODIS Clear Sky Radiances

- 2 New Products for Collection 5
- Consists of Granule, Daily and Eight Day global gridded products
- Composited radiances (reflectances) for MODIS observations where the cloud mask finds clear (> 95 % high confident clear)
- 25 km equal area global grid
- Reflectance Bands 1-7, 17-19, 26
- Thermal Bands 20-25, 27-36

# MODIS Clear Sky Radiances

- **Nine Statistics Saved for Each Grid:**
  - *Total number of observations*
  - *Number of clear observations*
  - *Sum of clear values*
  - *Minimum clear value*
  - *Maximum clear value*
  - *Sum of viewing zenith angles*
  - *Sum of clear-sky values squared*
  - *Sum of observed clear minus calculated clear values (for clear-sky bias calc.)*
  - *Sum of observed minus calculated clear values squared*

# Use of MODIS Clear Sky Radiances

- Bias correction for MOD06 Cloud Top Properties Product
- Bias generation for MOD07 Product
- QC for MODIS cloud mask
- Additional cloud mask test for temporal consistency over ocean night
- Shadow detection
- Input to ECMWF model

# Clear Radiance Processing Steps

- Generation of Calculated Clear Sky Radiances for Thermal Channels (used for bias calculation)
- Generation of granule level HDF file
- Generation of daily composited HDF file
- Generation of 8 day composited HDF file

# Calculated Clear Radiance File Creation (MOD\_PRCSRFM)

- Run forward model to provide calculated clear radiances for thermal bands 20-25, 27-36
  - 101 level Pressure-Layer Fast Algorithm (PFAAST) transmittance model
  - LBL RTM version 7.04
  - Inputs:
    - Global model GDAS vertical T/q profiles
    - Reynolds blended SST
- Binary flat file output product
- Interim product – not archived

# Granule Clear Sky Radiance File Creation (MODCSR\_G)

- Run granule based clear sky compositor to produce 9 statistics for each grid cell touched by the granule
  - Inputs:
    - MODIS cloud mask (MOD35)
    - MODIS Level 1B 1km file (MOD021KM)
    - MODIS calculated clear sky granule binary file (used for biases only)
- Output HDF file contains only statistics for grid cells which were found to contain clear observations as determined by the cloud mask
- Stand alone executable separated out of cloud mask software (PGE55)

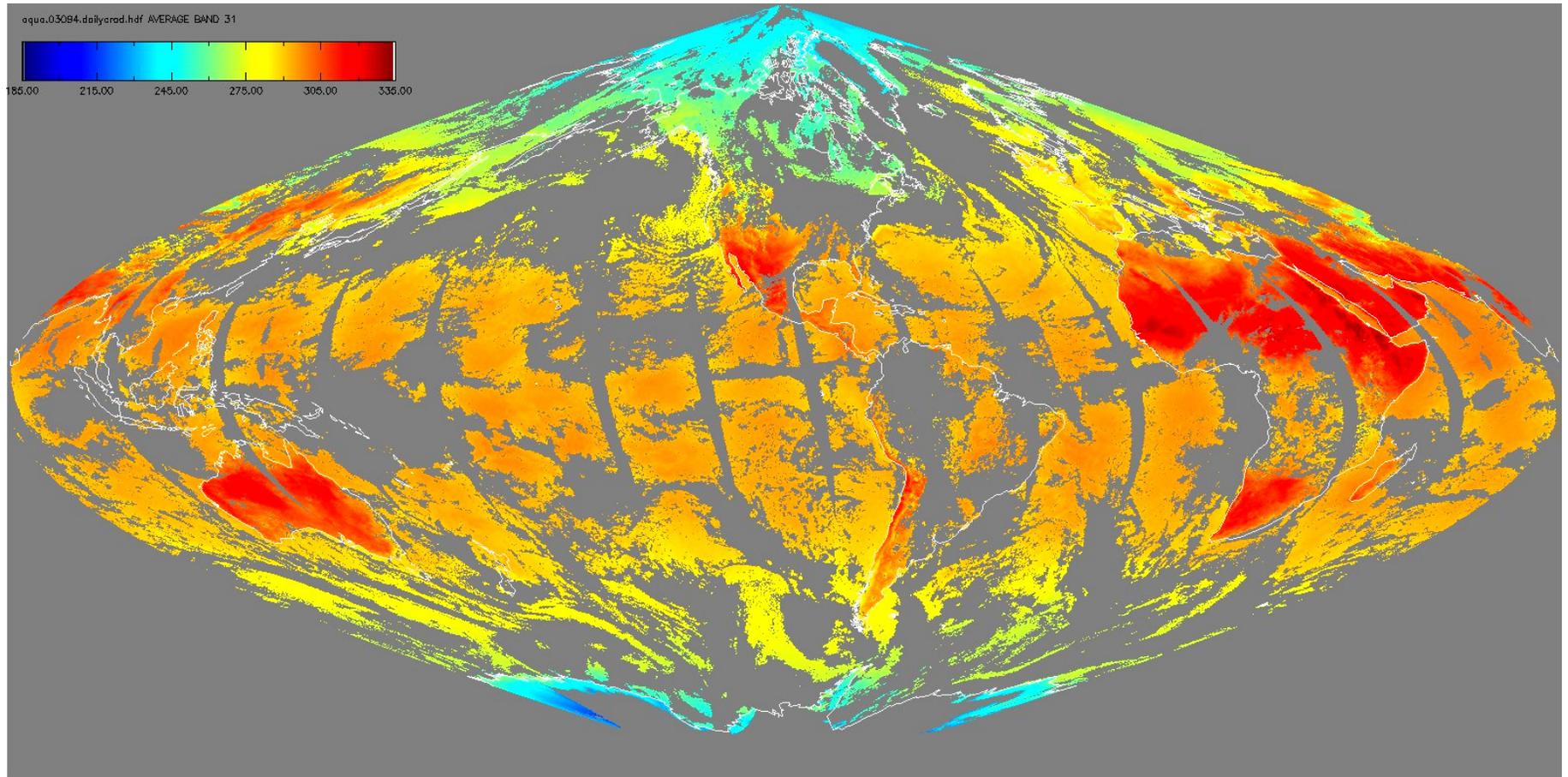
# Daily Clear Sky Radiance File Creation (MODCSR\_D)

- Run daily clear radiance file compositor to produce global day and night statistics for each grid cell
- Inputs:
  - MODIS granule based clear sky radiance files (MODCSR\_G)
- From the 9 statistics saved, clear radiance (reflectance) averages, biases, standard deviations and variances can be calculated for each grid cell
- New product (PGE85)

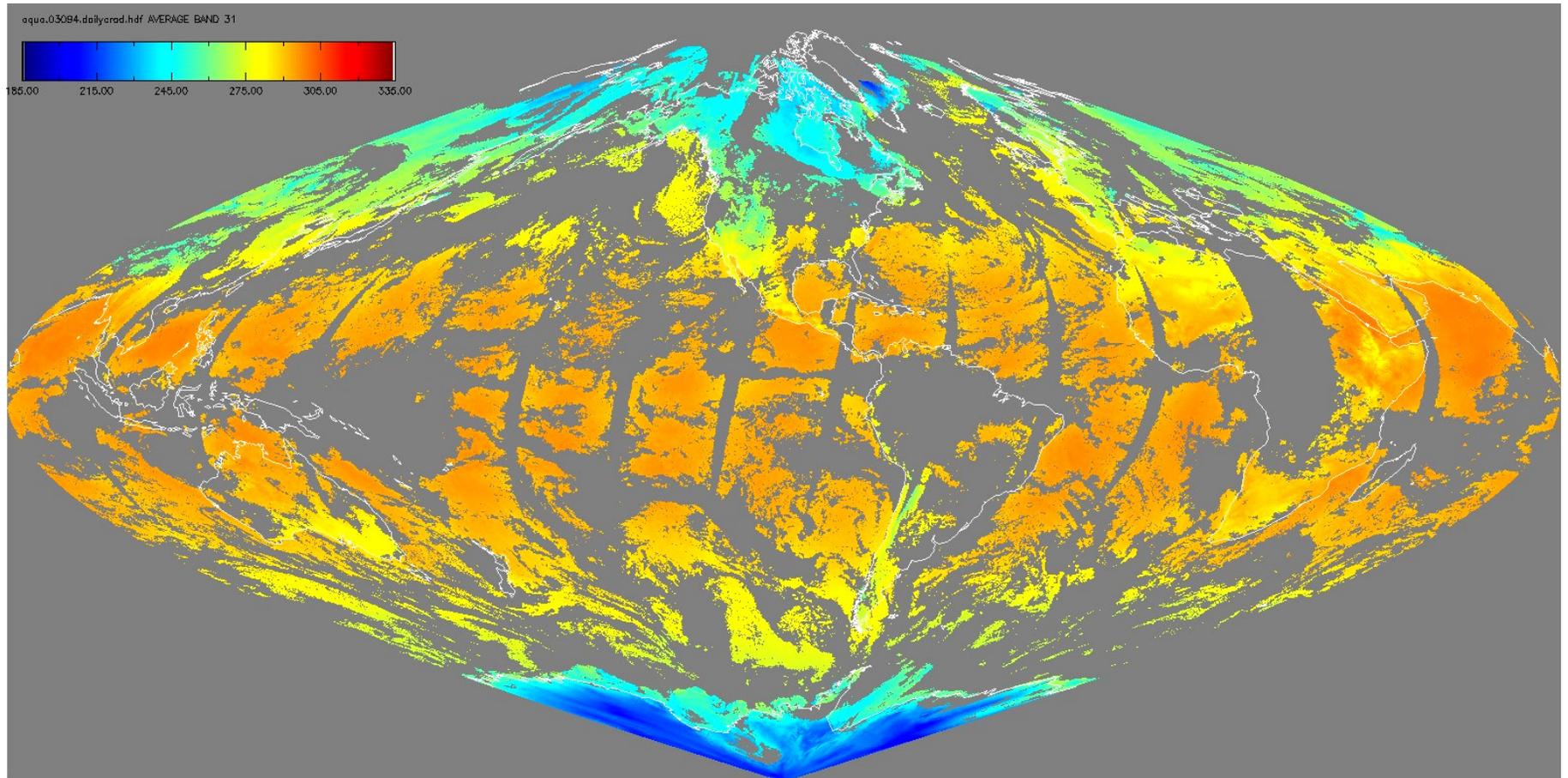
# Eight Day Clear Sky Radiance File Creation (MODCSR\_8)

- Run eight day clear radiance file compositor to produce global day and night statistics for each grid cell
- Inputs:
  - Daily MODIS clear sky radiance files (MODCSR\_D)
- From the 9 statistics saved, clear radiance (reflectance) averages, biases, standard deviations and variances can be calculated for each grid cell
- New product (PGE81)

# Global Clear Sky Composite Brightness Temperatures Daytime Band 31 Aqua 4 April 2003

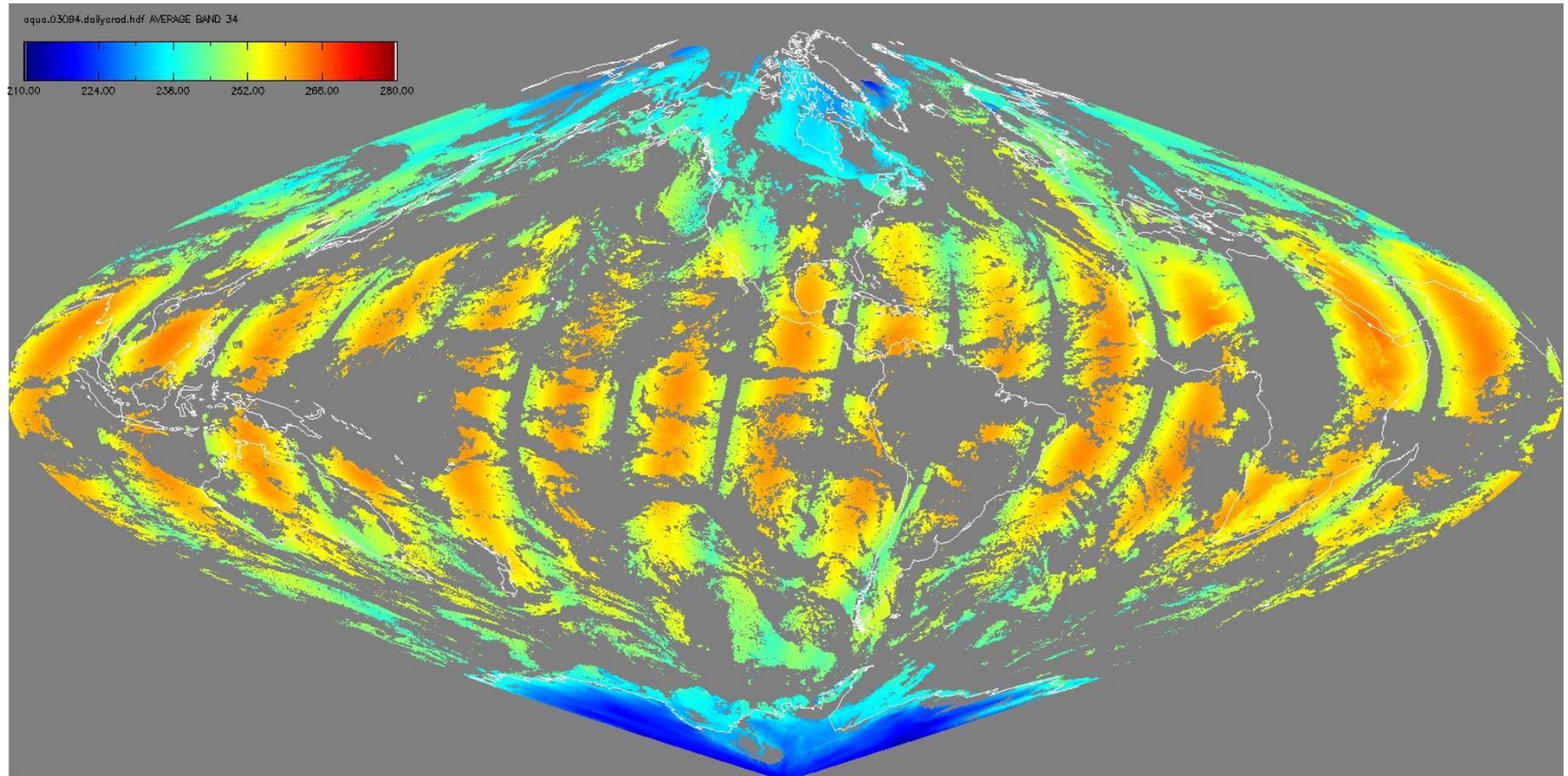


# Global Clear Sky Composite Brightness Temperatures Nighttime Band 31 Aqua 4 April 2003



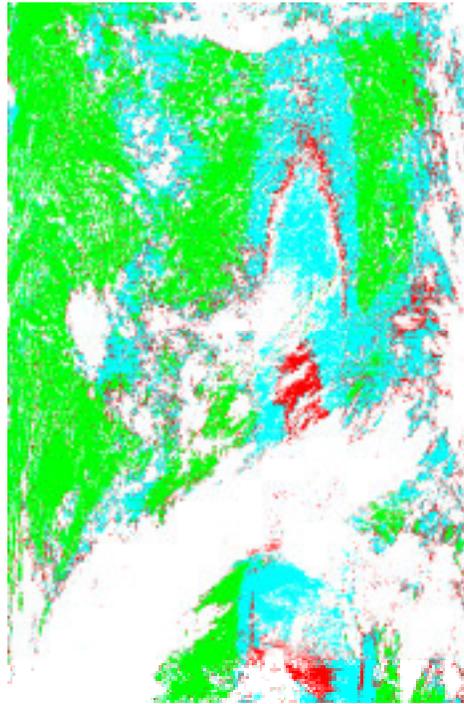
# Global Clear Sky Composite Brightness Temperatures

Daytime Band 34 Aqua 4 April 2003

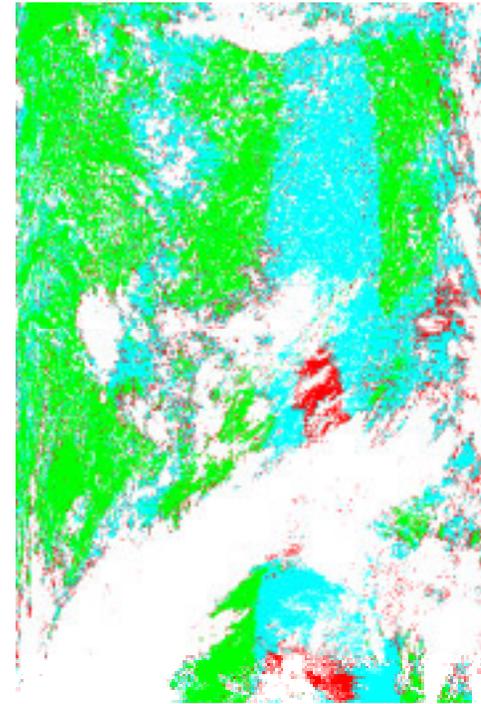




MODIS Band 2 Image

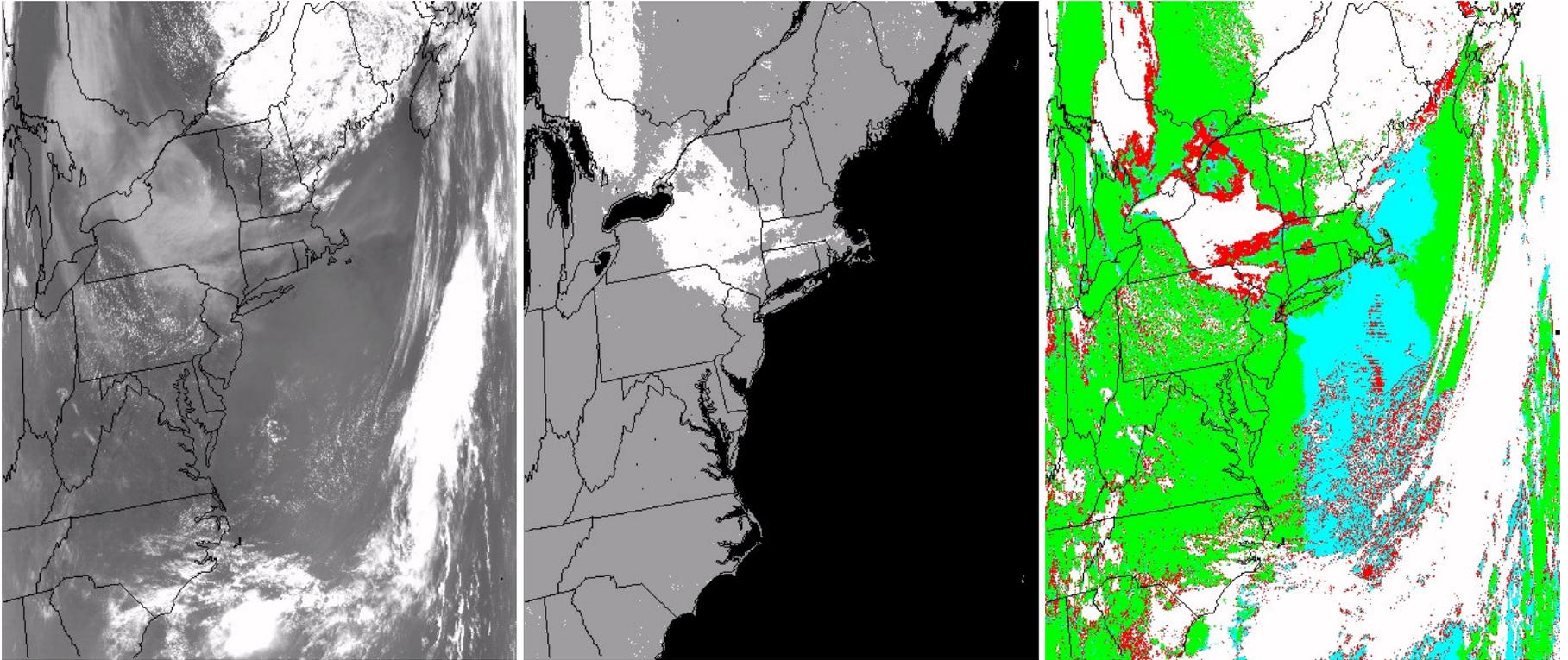


Collection 4



Collection 5

A threshold change was made to minimize the occurrence of uncertain and cloudy “rings” around the perimeter of sun-glint regions.



Terra MODIS band 3, “smoke mask”, and cloud mask for 6 July, 2002, 15:50 UTC.

## Clear-sky Radiance Data

Beginning with Collection 5 processing, a new process will generate clear-sky radiances from cloud mask results (MOD\_PR???). Daily and 8-day composites will be computed for bands ?? at 25-km resolution.

Statistics for each 25-km region will include:

Total number of observations

Number of clear observations

Sum of clear values

Minimum clear value

Maximum clear value

Sum of viewing zenith angles

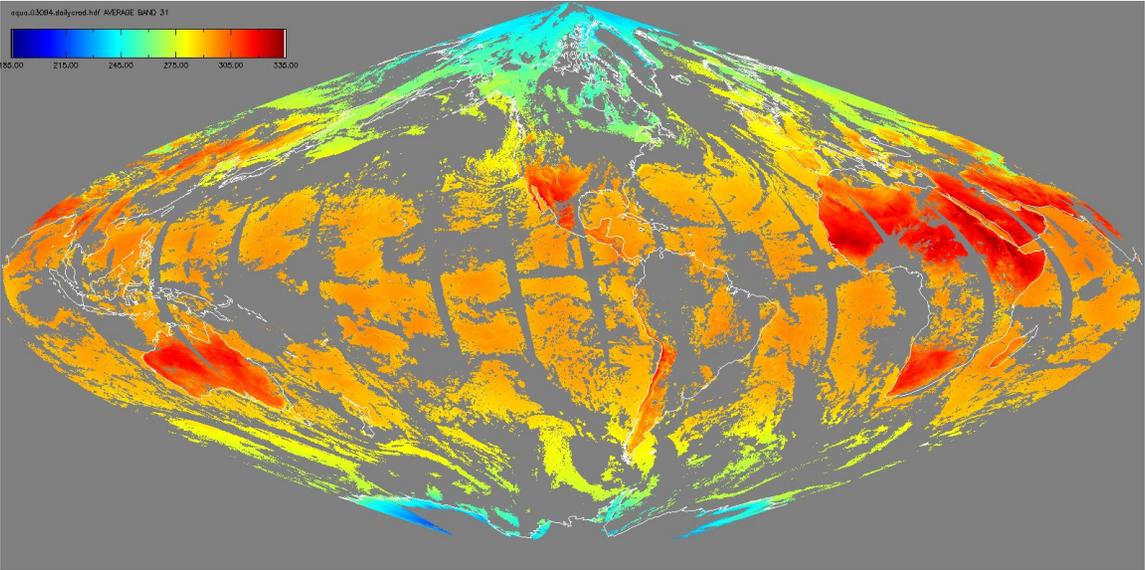
Sum of clear-sky values squared

Sum of observed clear minus calculated clear values (for clear-sky bias calc.)

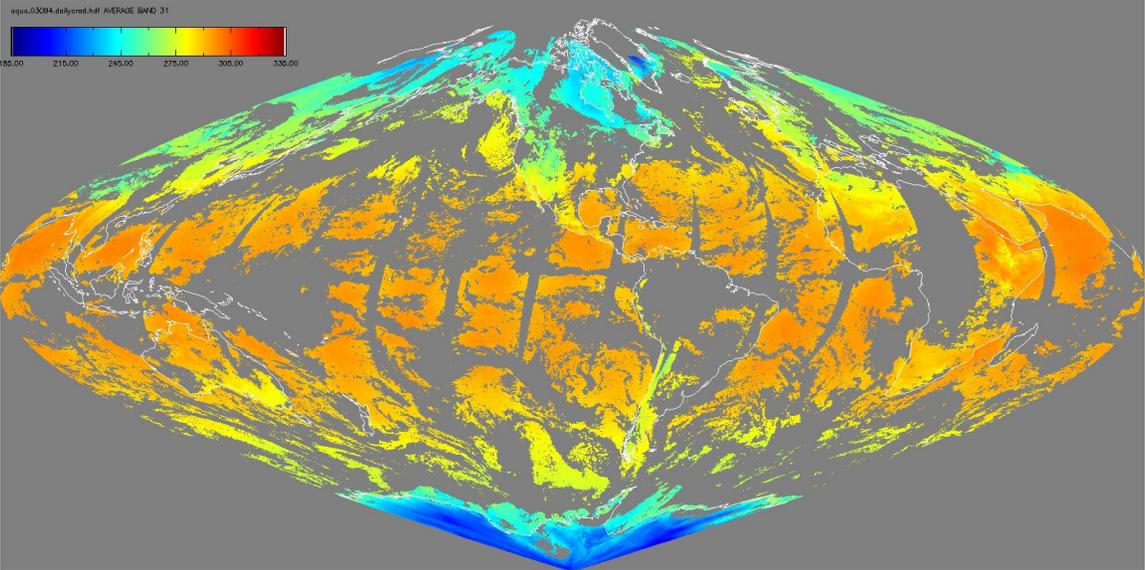
Sum of observed minus calculated clear values squared

# Aqua 11 $\mu\text{m}$ Clear-sky Brightness Temperatures

Day

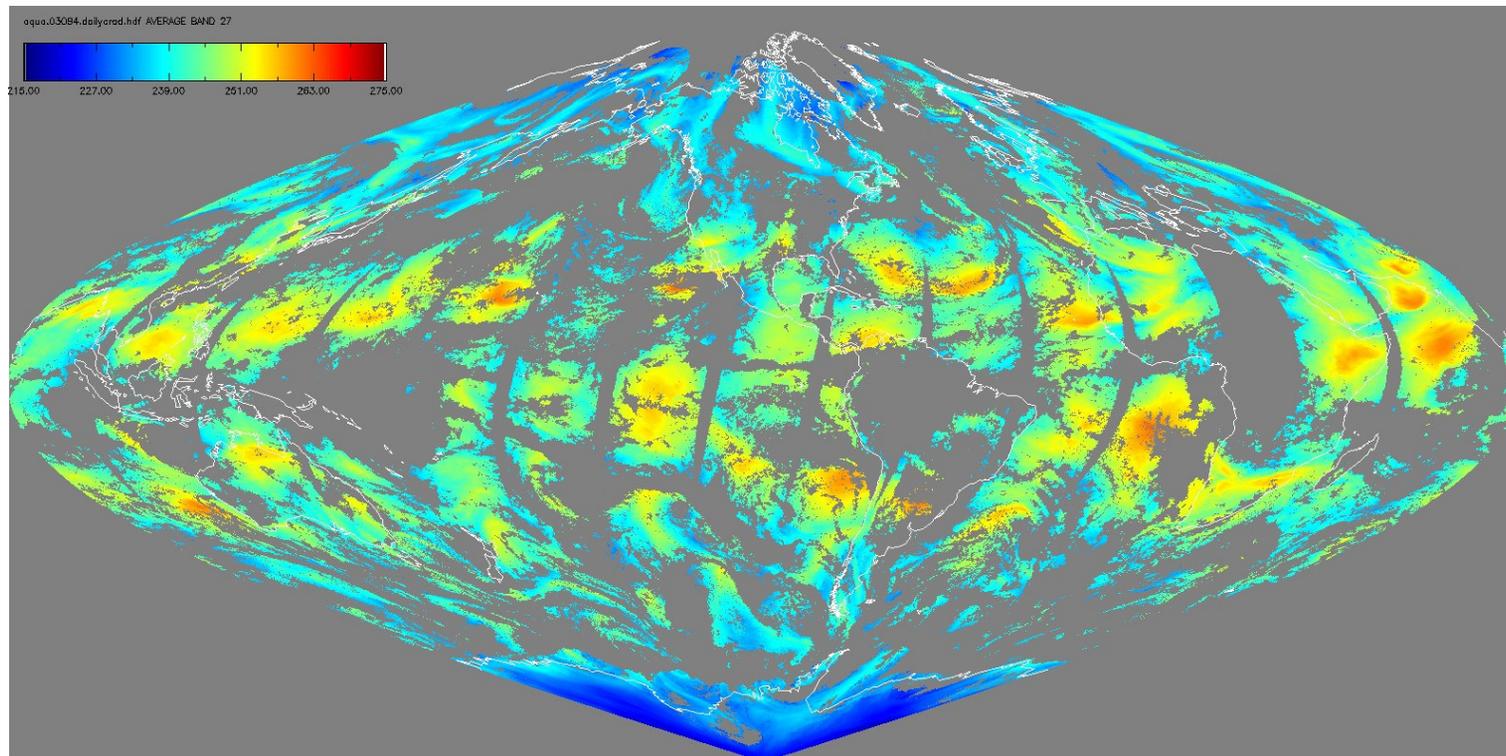


Night



April 4, 2003

# Aqua 6.7 $\mu\text{m}$ Night Clear-sky Brightness Temperatures



April 4, 2003